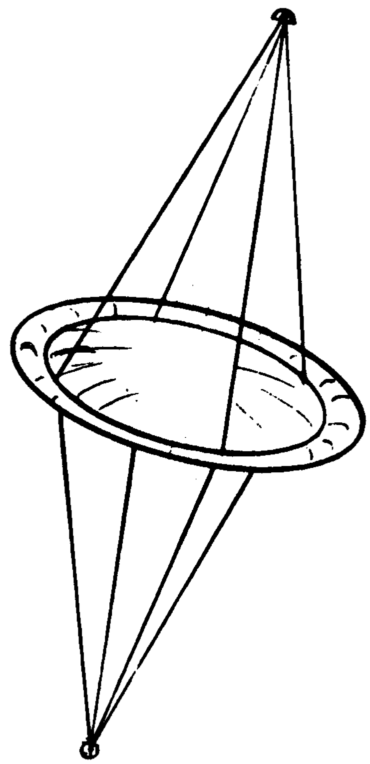
PasComSat Experiment

for

APOLLO APPLICATION PROGRAM



GER 12919

October 1966

NASw-1439 FEASIBILITY STUDY

OF

PASSIVE COMMUNICATION SATELLITES CONCEPT

FOR

THE APOLLO APPLICATION PROGRAM

Prepared For

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

LANGLEY RESEARCH CENTER

GOODYEAR AEROSPACE

SUMMARY

This technical report summarizes the data presented by Goodyear Aerospace Corporation (GAC) during a review meeting at NASA-Langley Research Center (LRC) on 25 October 1966, between the cognizant NASA and GAC personnel listed below:

NASA	GAC
W. Bressette - LRC	J. Altekruse
D. Grana - LRC	F. Stimler
J. Cooper - LRC	A. Buxton
J. Humble - LRC	J. Huber
H. Lawrence - LRC	J. Dees
J. Adams - LRC	
H. Price - LRC	
C. Bayer - MSFC	

A contract requirement, the purpose of the technical review was to present the results of the third and fourth months of the program. The results of the first two months of the program are given in GER-12853* and certain technical areas must be coordinated with the present report to obtain the complete picture. These data reflect the present AAP philosophy, as defined at NASA-MSC and MSFC, to ensure experiment compatibility. Once again, the 1000 lb baseline design is used as a guide for experiment, instrumentation, task and equipment definition and does not necessarily represent maximum or minimum LenSat size for experiment considerations. The baseline size was chosen to give complete rf earth coverage at maximum lens radius of curvature for a total weight of 1000 lbs.

Detailed definitions of PasComSat experiments are given along with pertinent design and tolerance information. An experiment altitude of 500 nautical miles was chosen as a representative low altitude condition compatible with early

*GER-12853, "Feasibility Study of Passive Communication Satellite Concepts for the Apollo Program", Goodyear Aerospace Corporation, Akron, Ohio, September 1966.

AAP flight plans which include manned participation. The baseline design can also be considered for a synchronous altitude experiment. The synchronous altitude case has the advantage of making it easier to conduct rf tests via ground based equipment.

It is recommended that test modes A and B be combined and the CSM and SIV-B be used for the primary equipment platforms while the RMU is used for closer evaluation of geometry and structural integrity of the PasComSat during deployment and rigidization. The packaged PasComSat is stored on the AAP experiment rack. The docking and deployment techniques suggested are compatible with present AAP plans. The PasComSat is located 600 ft. from the CSM and SIV-B to prevent interference or entanglement during deployment.

In addition to the primary experiments of deployment and rigidization, structural evaluation, material properties, stabilization and damping and RF evaluation, the following secondary experiments are suggested:

(1) lens buckling
(2) long term gravity gradient stabilization
(3) material damping evaluation
(4) preliminary communications tests
(5) extended materials exposure at space environment
(6) solar pressure effects

The items of interest and their range of values are tabulated for information purposes. The actual values and the tolerances anticipated will be finally established during a preliminary design phase at a later date.

A review of the orbital dynamics indicates that the deployed PasComSat, after one orbit, will be approximately 1700 ft. ahead and 350 ft. below its initial position relative to the SIV-B and the CSM. Further considerations must take into account the solar pressure effects in addition to the drag effects.

PasComSat configurations of 10,000 lbs and 100 lb system weights were also investigated and are presented for general information.

The given equipment and instrument list represents a first pass effort. Data will be updated prior to submittal of the final report.

A final report outline is indicated to stimulate comment and ensure adequate coverage of the study results.

Technical specialists in the areas of stabilization, rf experimentation and astronaut participation reviewed, in detail, the summary charts presented herein. The charts are self explanatory. In summary, the items remaining to be accomplished on the program were indicated along with the suggested follow-on effort.

In general, summary charts were used in this review. The detail calculations and definitions of assumptions will be incorporated in the final report, since the purpose of the technical review was to bring all participants to the same understanding of test philosophy and goals without spending too much time on minute details.

TECHNICAL BRIEFING

AT

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

LANGLEY RESEARCH CENTER

25 OCTOBER 1966

PasComSat Experiments

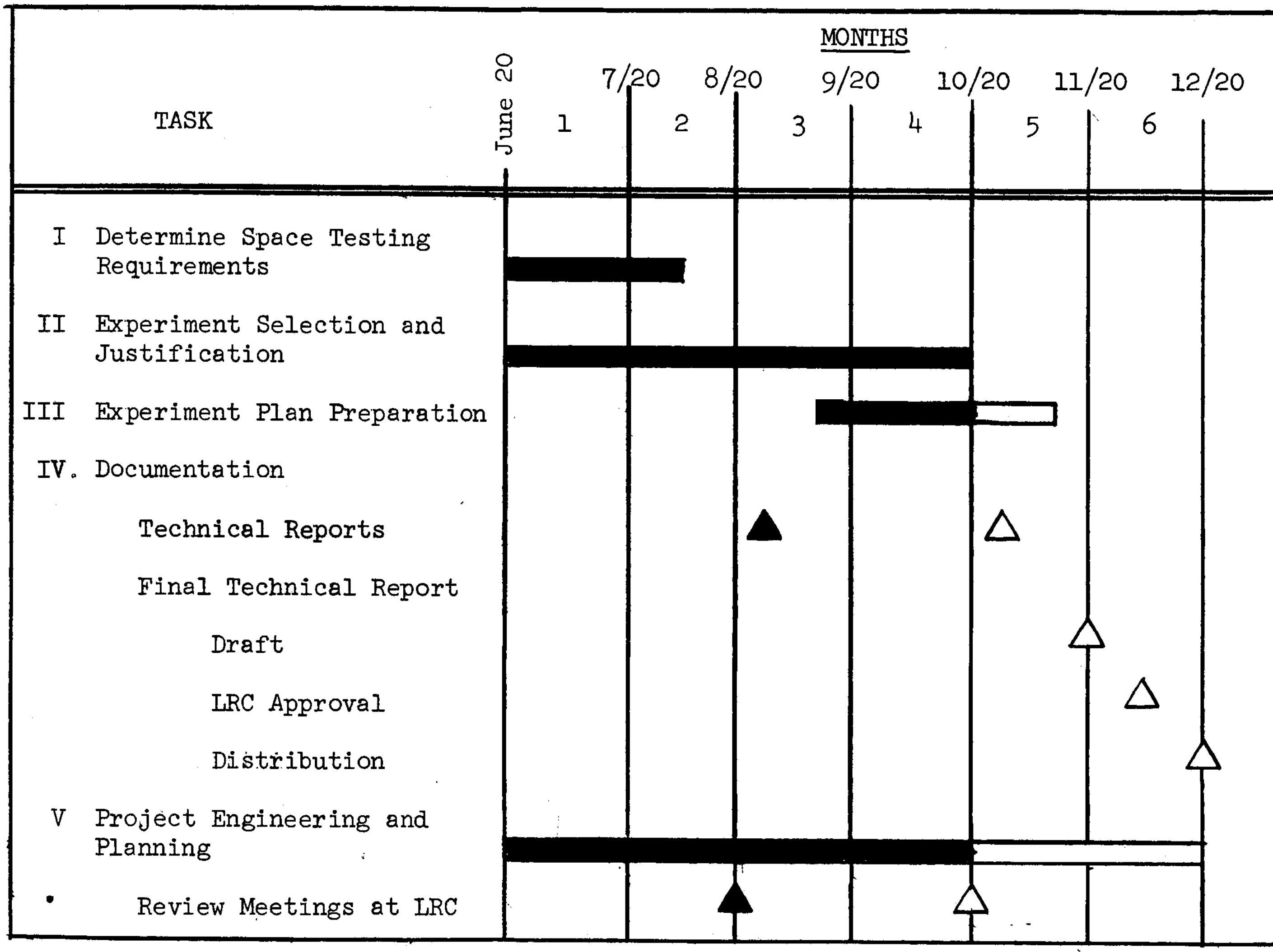
for

APOLLO APPLICATION PROGRAM

NASw-1439 - FEASIBILITY STUDY OF PASSIVE COMMUNICATION SATELLITE CONCEPTS FOR THE APOLLO APPLICATION PROGRAM

The program schedule shows that approximately one (1) month remains until delivery of the draft of the final report to LRC for review and approval. Technical discussions have been held by LRC and GAC personnel with cognizant NASA-MSC and MSFC personnel to acquaint them with the program goals and ensure compatibility with the AAP Experiments philosophy.

PROGRAM SCHEDULE - PasComSat AAP EXPERIMENT



This master program plan represents the major areas of interest and effort in the development of a PasComSat system over a period of approximately 18 to 24 months. GAC background on similar programs has indicated this type of breakdown as an efficient means of expediting and evaluating program progress and facilitating technical assignment.

MASTER PROGRAM PLAN - PasComSat DEVELOPMENT

TASK	MONTHS AFTER GO AHEAD
PRODUCT DESIGN	
SYSTEM ANALYSIS AND INTEGRATION	
PROCUREMENT	
*GROUND TEST DEVELOPMENT PLAN	
Test Plan Documentation	
Materials Development	
Fabrication Techniques Dev.	
Component Checkout	
Subsystems Checkout	
Prototype Design Verification Tests	
Prototype Flight Acceptance Tests	
Fabrication/Assembly/Checkout	
Area Make Ready	
Tooling - Design and Fabrication	
Prototype Units	
Spare Parts	
Flight Units	
Payload Handling Document	
Reliability and Quality Control	
Payload Integration/Booster	
Design (Design Freeze Date)	
Procurement	
Tooling	
Fabrication	
Checkout	
Launch Support	
Hangar Checkout Test Plan	
Payload Delivery	
Spare Parts Delivery	
Handling Fixtures Dev.	
Payload Checkout - Launch Site	
Launch Site Crew - Test Support	
Flight Test Data Analysis	
Operational Checkout	
Performance Analysis	
Management and Documentation	
Milestone/Cost Charts	
Monthly Progress Reports	
Final Technical Report	
Technical Review Meetings	

This table indicates the ground tests which should be considered during development of the lenticular PasComSat system. This plan is useful to the specialist in defining the state of the art and future requirements in his technical discipline. These data will be incorporated in the final report.

From the list, it may be possible or advisable to pinpoint work areas of immediate interest to enhance development of the PasComSat system at a later date.

GROUND TEST DEVELOPMENT PLAN - BASE LINE DESIGN

ITEM	SAMPLE SIZES	MODEL SIZES	GENERAL REMARKS
Materials Development Tests/ Characterization Data			
Lens			RT and Env. Chamber Tests
Torus			Weight Breakdown
Booms			Seam Data
Rim			Physical Characteristics
Solar Sail			
Fabrication Techniques Development			
Materials			
Components			
Tooling			
Assembly			
Attachments			
Seaming			
Process Control			
Quality Control			
Component Checkout			Fabrication and Inspection
Lens			Physical Data Tolerance Test Fixture Design and Fabrication Water Table Deployment Env. Chamber Tests Model Tests Full Scale Components
Torus			
Booms			
Rim			
Solar Sail			

GROUND TEST DEVELOPMENT PLAN (Continued)

ITEM	SAMPLE SIZES	MODEL SIZES	GENERAL REMARKS
Component Checkout (Cont'd)			
Attachments			
Junctions			WT and Moment of Inertia Determination/Verification
Hardware Tests			
Subsystems - Stab., Damping			
R.F. Performance			
Subsystems Checkout			
Canister Assembly			Thermal Distortion Data
Inflation System			
Control System			
Spacecraft Interface			
Orientation and Stabilization			Satellite Mass Distribution
Payload Packaging and Deployment			(RT and Chamber Tests)

BASE LINE DESIGN EXPERIMENTS

Deployment and Rigidization

Structural Evaluation

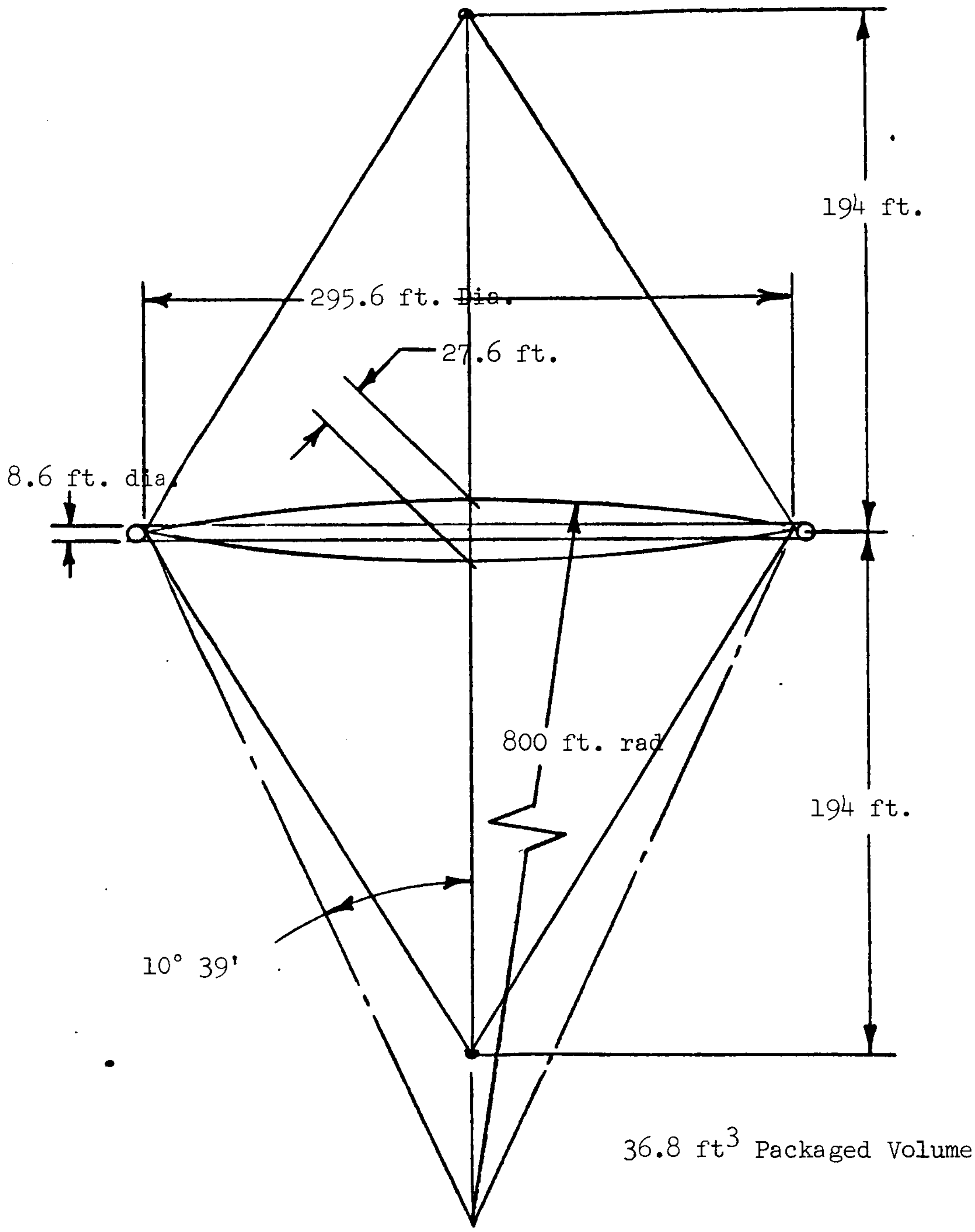
Material Properties

Stabilization and Damping

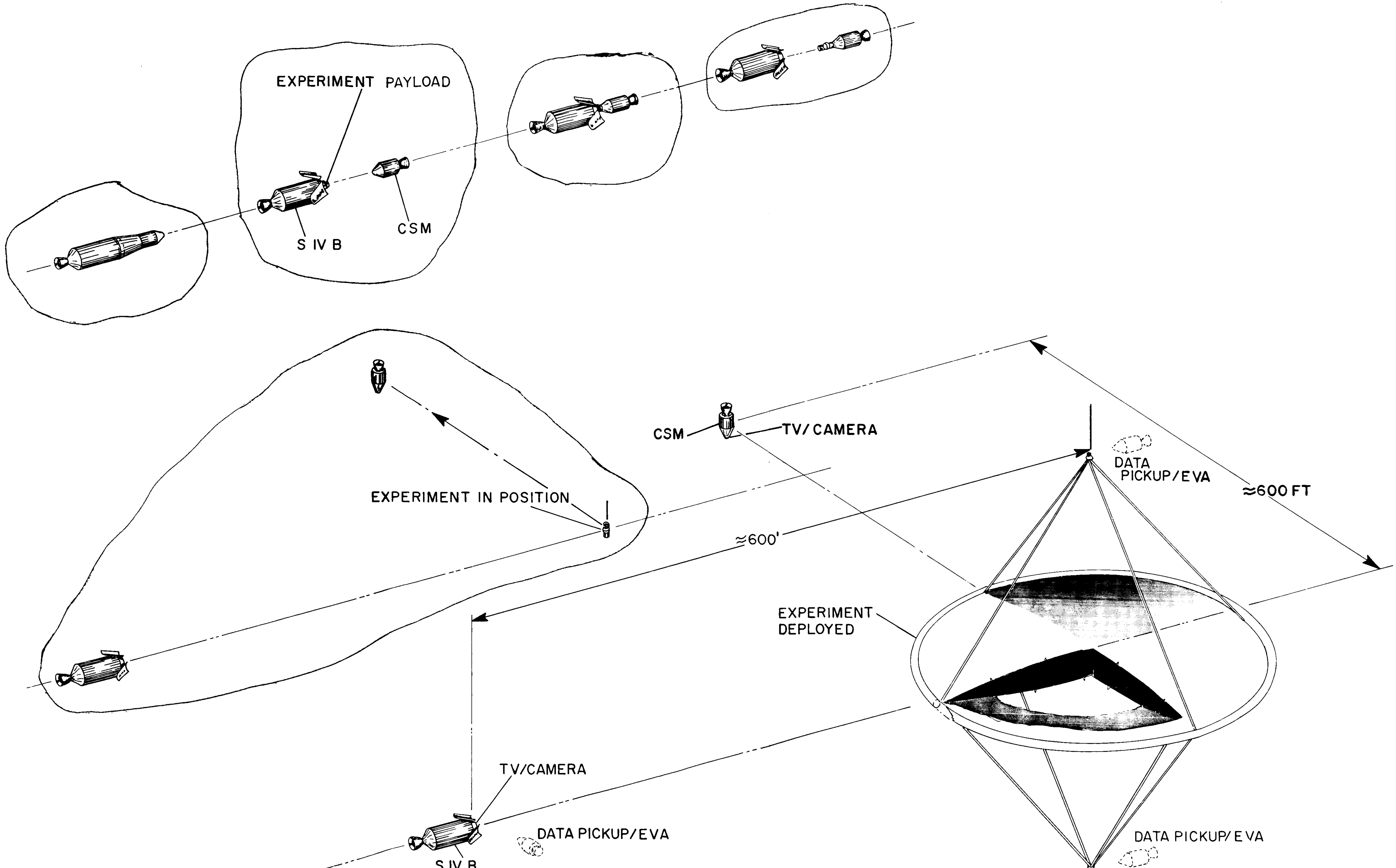
RF Evaluation

NOT CONSIDERED AT THIS TIME

Station Keeping



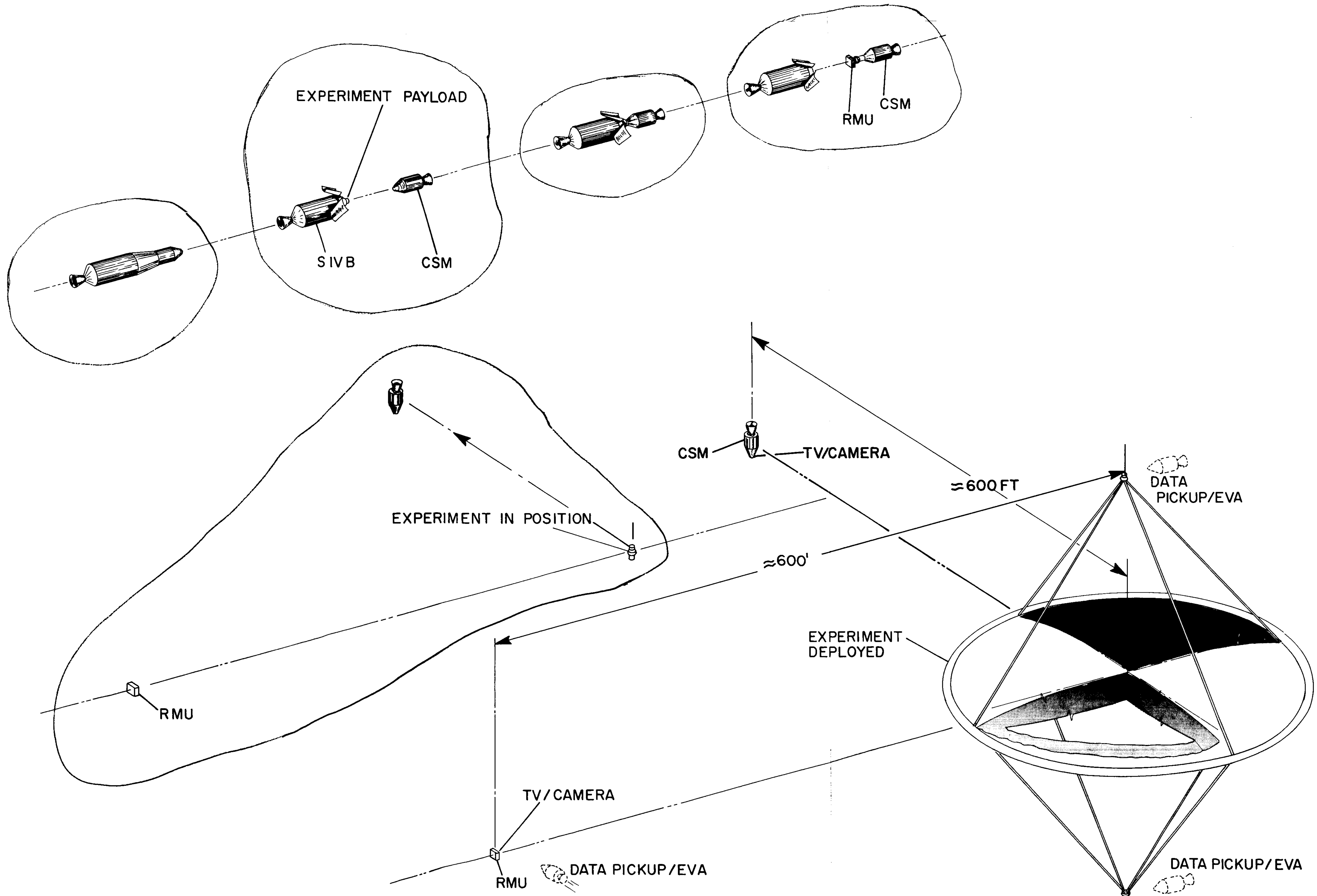
Base Line Design
1000 lbs System Wt.



TEST MODE A CSM WITH S IV-B

GOODYEAR AEROSPACE CORPORATION AKRON 15, OHIO

13/14



TEST MODE B – CSM WITH RMU

GOODYEAR AEROSPACE CORPORATION AKRON 15, OHIO

10 DEPLOYMENT AND RIGIDIZATION

Test	Items of Interest	Range	Tolerance
Payload Separation from CSM	--	--	--
Satellite Deployment (In Sunlight)	Time/Temperature	10 minutes in sunlight	+ 5 min - 2 min
Canister Separation	Separation Velocity	<0.1 ft/sec very slow	?
Torus Inflation	Pressure/Time	0.152 PSI	+ 20% - 0%
Lens Rigidization	Pressure/Time	0.0000245	+ 20% - 0%
Boom Rigidization	Pressure/Time	(?)	+ 20% - 0%
Forces and Reaction	(Note Action)		

20 STRUCTURAL EVALUATION

Test	Items of Interest	Range	Tolerance
Structural Integrity	Overall Observation	--	Tolerance in dimensions is prescribed by manufacturing limitations and it is not necessary to be measured. Visual observation or comparison of movies will be sufficient to judge the dimensional integrity of the satellite.
Dimensional Accuracy Torus Sectional Dia. Torus Ring Dia. Boom Length Boom Dia. Lens/Rim Dia. Lens Height	Lengths of items described in the left column should measure as shown in the adjacent right column for a successfully deployed satellite.	 8.6 ft. 295.6 ft. 243.6 ft. 2.6 in. 295.6 ft. 27.6 ft.	
Lens Surface Characteristics	1. Smoothness	1. Spherical caps for lens	1. ?
	2. Frequency of tears	2. Unpredictable	2. ?
Distortion Analysis Rim Deflection	Out of Plane Deflection	Deflections in general are expected during maneuvering of satellite	3 ft.
Boom Bending	Midpoint Deflection		?
Boom Torsion	Angle of Twist		(1)
Thermal Distortion	Deflections in general		?
Structural Damping	Natural frequency		?
Buckling Tests (At end of Experiment) Boom Lens	Load that causes failure	(2)	

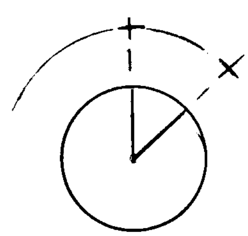
(1) The angle of twist of the booms is limited from considerations of stabilization system performance.

(2) At the end of the experiment axial compressive loads and torques may be used to collapse the booms and accelerations (inertia forces applied prior to collapsing the booms) to collapse the lens.

30 MATERIAL PROPERTIES

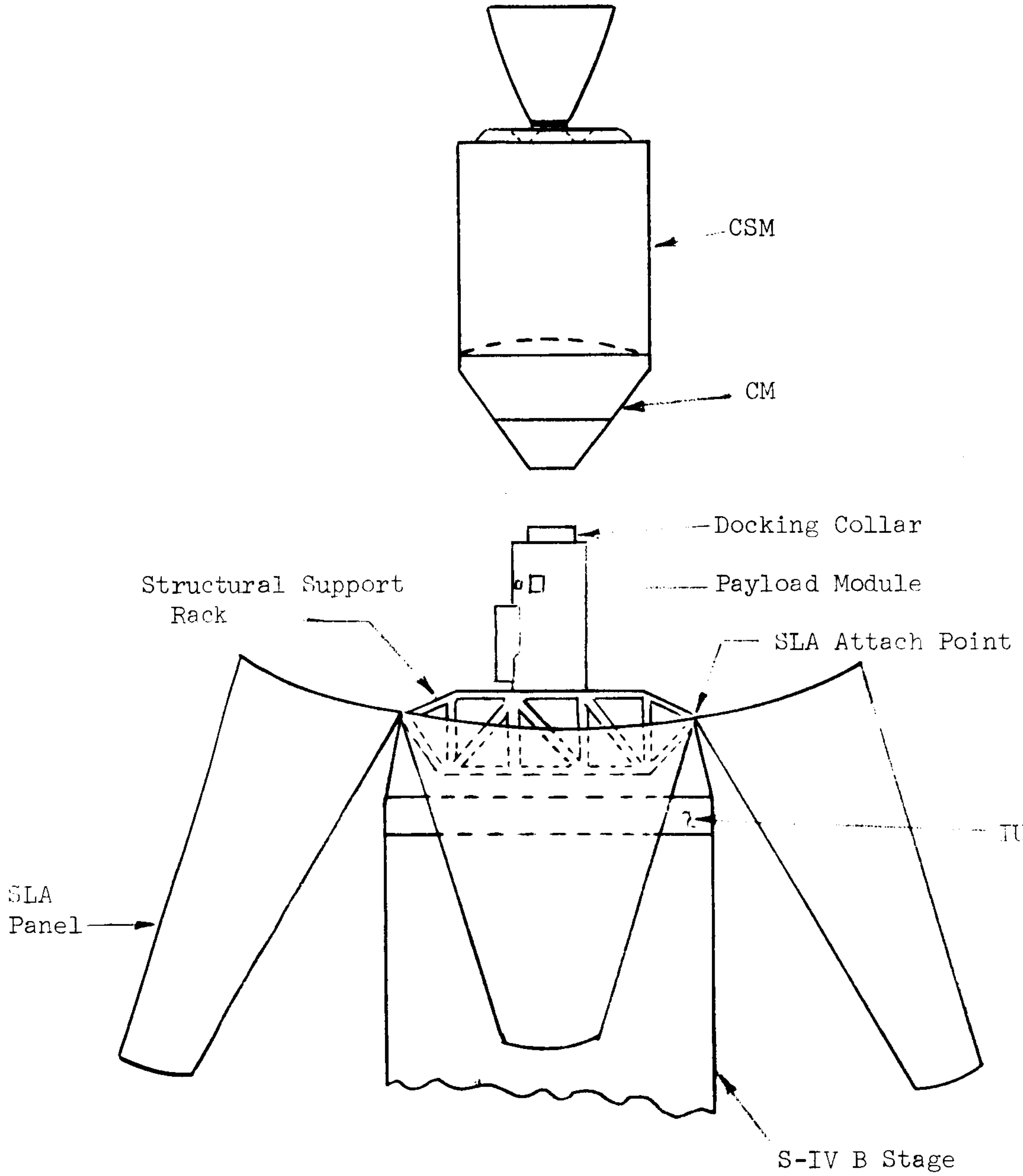
Test	Items of Interest	Range	Tolerance
Film Photolyzation Analysis			
Rate	Measure rate at which film photo degrades and evaporates	Time: 0-48 hrs. Wt. Chg. 0 = 1 oz/yd^2	
Residue	Measure amount of film remaining following long exposure	Time: 2-30 days 1 oz/yd^2 - .01 oz/yd^2	± 1%
Hot/Cold Cycling Effects	Measure effect of temp. on degradation rate and effect of extremely low temp. due to orbiting dark side of earth	+300° F to -400° F	
Space Environment Effects	Vs. Time		
Color Changes	Measure change of α_s		
Wire Grid Integrity	Measure strength of wire grid joints		
Junctions	Measure strength of seams		
Distortion	Measure degree of surface distortion in lens, booms and torus		
Hot/Cold Cycling	Measure effect Hot/Cold Cycling on distortion surface contour, seam strength, junctions, etc.		

40 STABILIZATION AND DAMPING

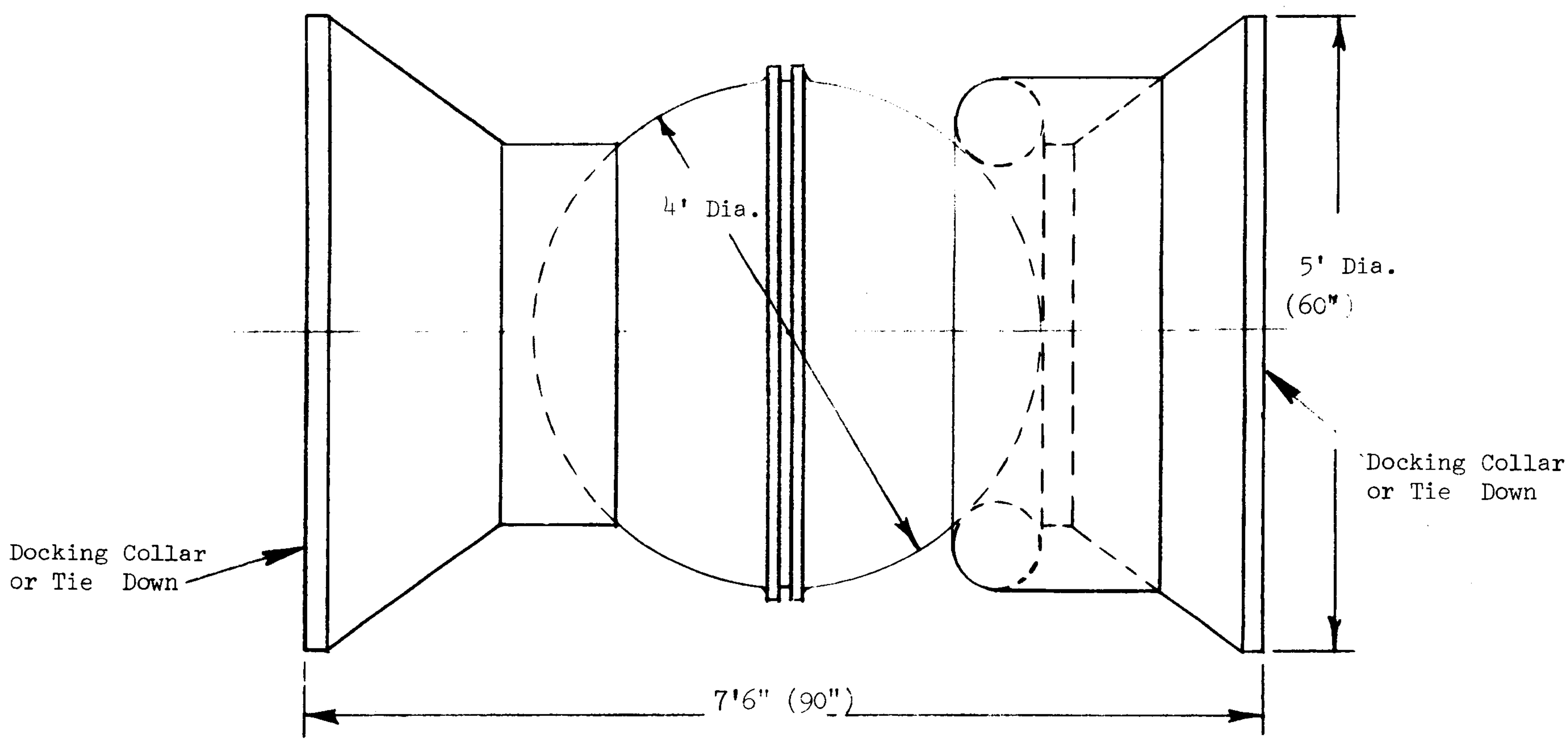
Test	Items of Interest	Range	Tolerance
Initial Stabilization Capture Analysis	Attitude Angle vs time	Unlimited	± 3° all axes
Satellite System Distortion	STEM boom distortion	±20% length	± 1 ft.
	Tetrapod boom distortion	± 5% length	± 1 ft.
	$\Delta = \vec{C_g} - \vec{C_p}$	±20% ft.	± 1 ft.
Stabilization/3 Axis Accuracy	Libration Error Amplitude/Frequency		
Pitch		$-10° < \theta < +10°$ $-90 < \theta < +90$	± 1° ± 3°
Yaw		$-10 < \psi < +10°$ $-360 < \psi < +360$	± 3° ± 10°
Roll		$-10° < \phi < +10°$ $-90° < \phi < +90°$	± 1° ± 3°
Damping Rates/3 Axis	Time Constants	τ_θ <30 days τ_ϕ <30 days τ_ψ <90 days	± 2 days ± 2 days ± 7 days
Mobility	°/Month	30 to 100°/mo	± 2°/mo
			
Orbit Eccentricity			
EM Energy Torques			
Satellite Orientation Control			

50 RF EVALUATION

Experiment	Parameter	Range	Tolerance
Radar Cross Section To Evaluate: surface tolerance; seam effects; diffraction effects; blockage; canister, booms; vehicle interference; boom tolerances; surface transmissivity effects; fading effects.	a) Frequency	1.0 - 10 gHZ Vary in small increments to separate effects (blockage, fading, and transmission effects).	-- Kilohertz tolerance
	b) Range	23 - 230 miles minimum as f (frequency) 40-400 for null investigation	Not critical
	c) Aspect angle	± 20° minimum 40° Bistatic	--
	d) Polarization	2 linear CP for cross check of boom effects.	-- 1 db
	e) Modulation	CW Pulse	-- 0.6 μsec. minimum pulse length
Antenna Tests To evaluate above except fading and blockage. Does much better on surface tolerance effects.	a) Frequency	0.1 - 10 gHz (use several, widely separated)	1%
	b) Range	2.5 - 400 miles minimum as f (frequency)	
	c) Aspect Angle	10 beamwidths BW = 70 λ/D	
	d) Polarization	Use 2 linear	--
	e) Modulation	(Same as above)	
Communication Test To evaluate effects of fading and scintilation	a) Carrier frequency		
	b) Single vs double sideband		
	c) Transmission clarity		
	d) Signal to noise		

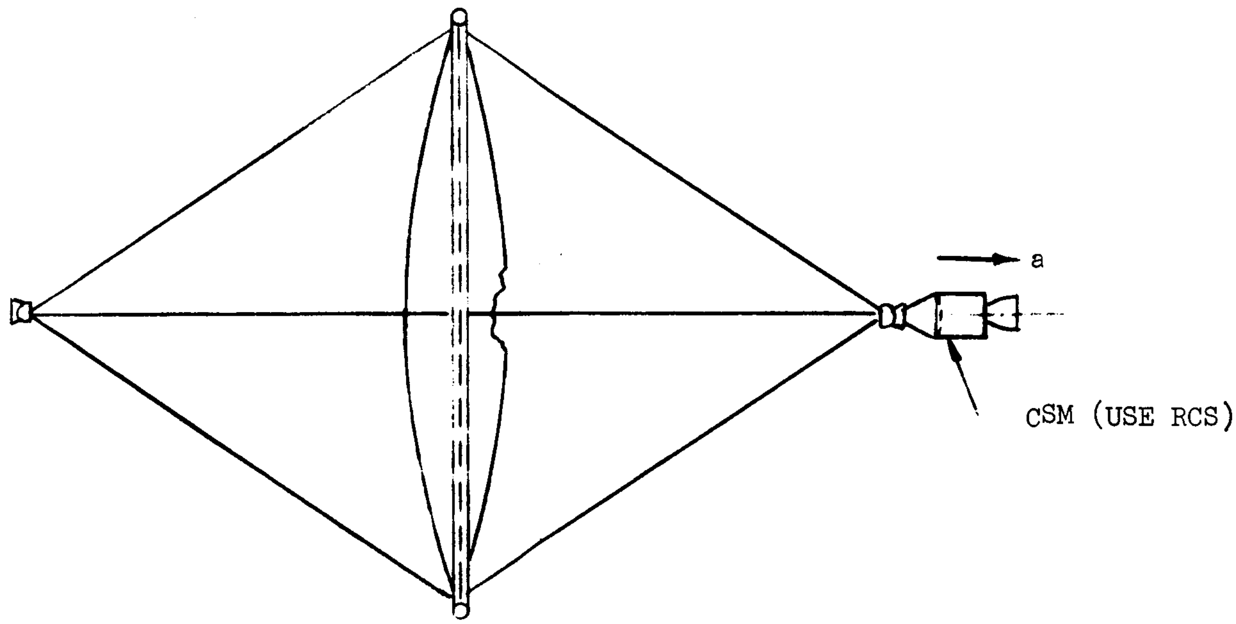


SKETCH OF MSFC-AAP EXPERIMENT RACK



Potential PasComSat Experiment Package

LENS BUCKLING EXPERIMENT



Method - Tweak Reaction Control Jets

Equations of Motion

$$\theta = \theta_o \left[1 + \frac{B \rho_o \; r_o}{\theta_o} \left(4 \cos \theta_o + \frac{3}{2} \theta_o^2 - 4 \right) \right]$$

$$r = r_o \left[1 + 2 B \rho_o \; r_o \; (\sin \theta_o - \theta_o) \right]$$

where

$B = \dfrac{C_D A}{2m}$

ρ = density

r = radius

θ = true anomaly

Subscript o = umperturbed orbit

Limitations

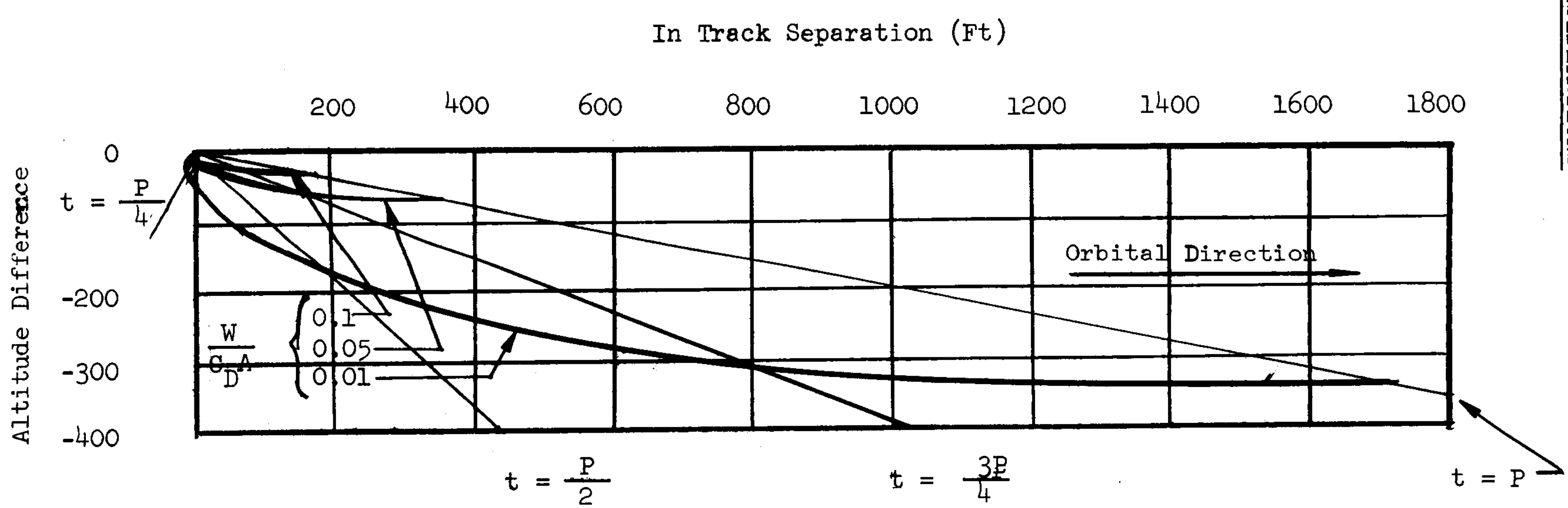
r_o constant

ρ_o constant

$\theta - \theta_o$ small

$r - r_o$ small

eccentricity - small



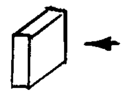
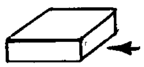
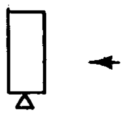
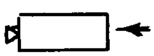
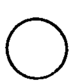
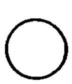
Note: $P = 6150$ sec
$h = 500$ n mi
$\rho = 0.3 \times 10^{-16}$ slug/ft^2

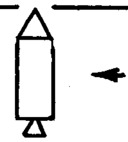
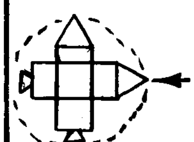
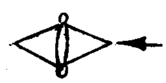
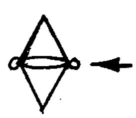
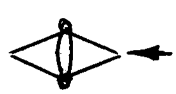
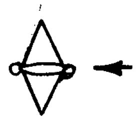
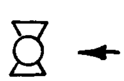
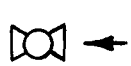
Values After Two Orbits

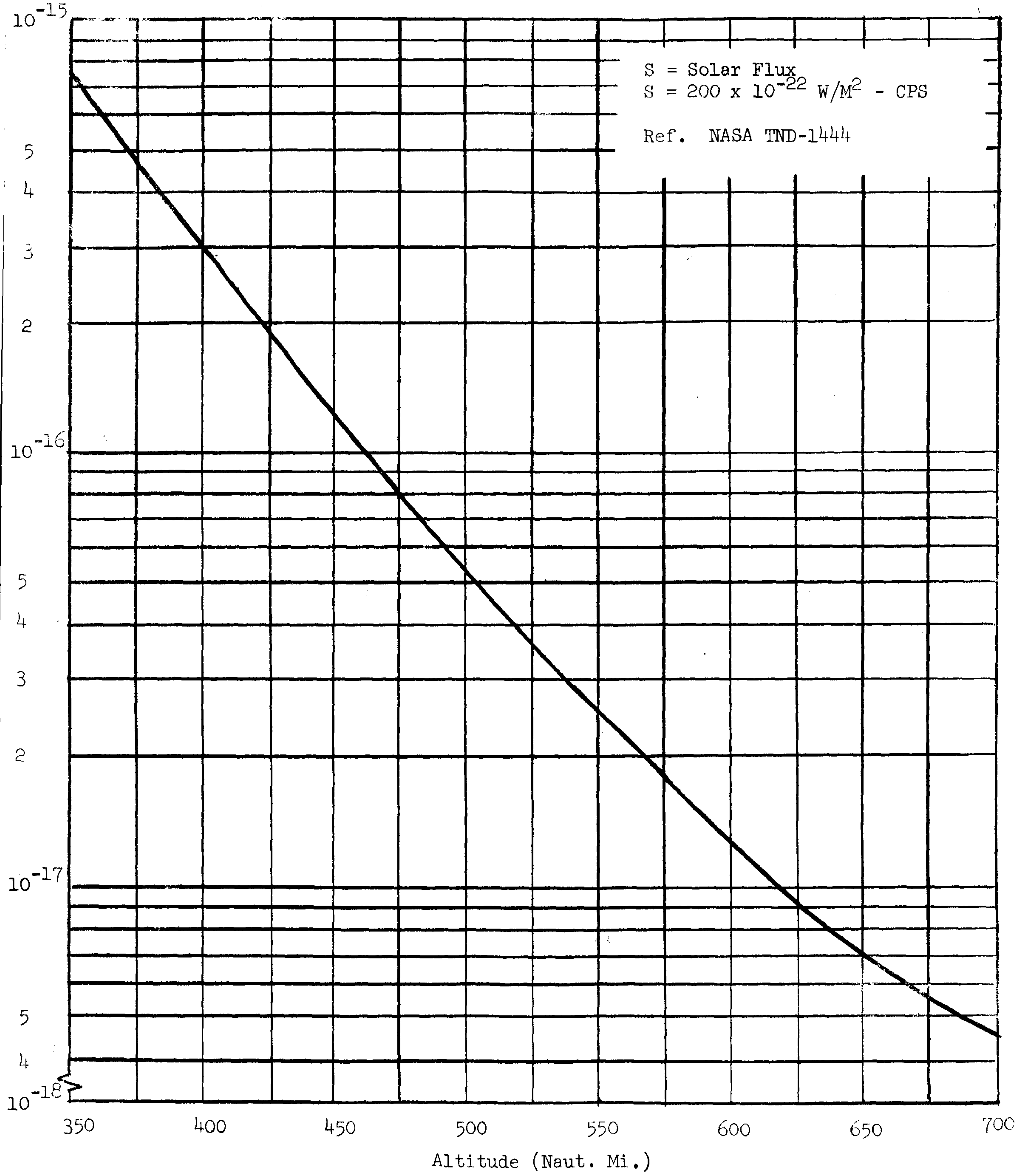
W/C_DA (PSF)	Alt. Diff. (Ft)	In Track Sep. (Ft)
0.1	70	650
0.05	140	1300
0.01	700	6500

Atmospheric Drag Effects Only

DRAG DATA ON CRITICAL EXPERIMENT COMPONENTS

Item	Sketch	$\frac{W}{C_D A}$ (#/ft^2)	Area, Ft^2	Wt, #	Remarks
RMU		19	4.34	180	
		30	3.12	180	
S IV B		11.3	626.4	30,000	S IV B Empty Wt - 23,120 #
		27.4	366	30,000	
Reference Data					
Echo I		0.0069	--	139	100 Ft.Dia.
Echo II		0.0132	--	500	135 Ft.Dia.

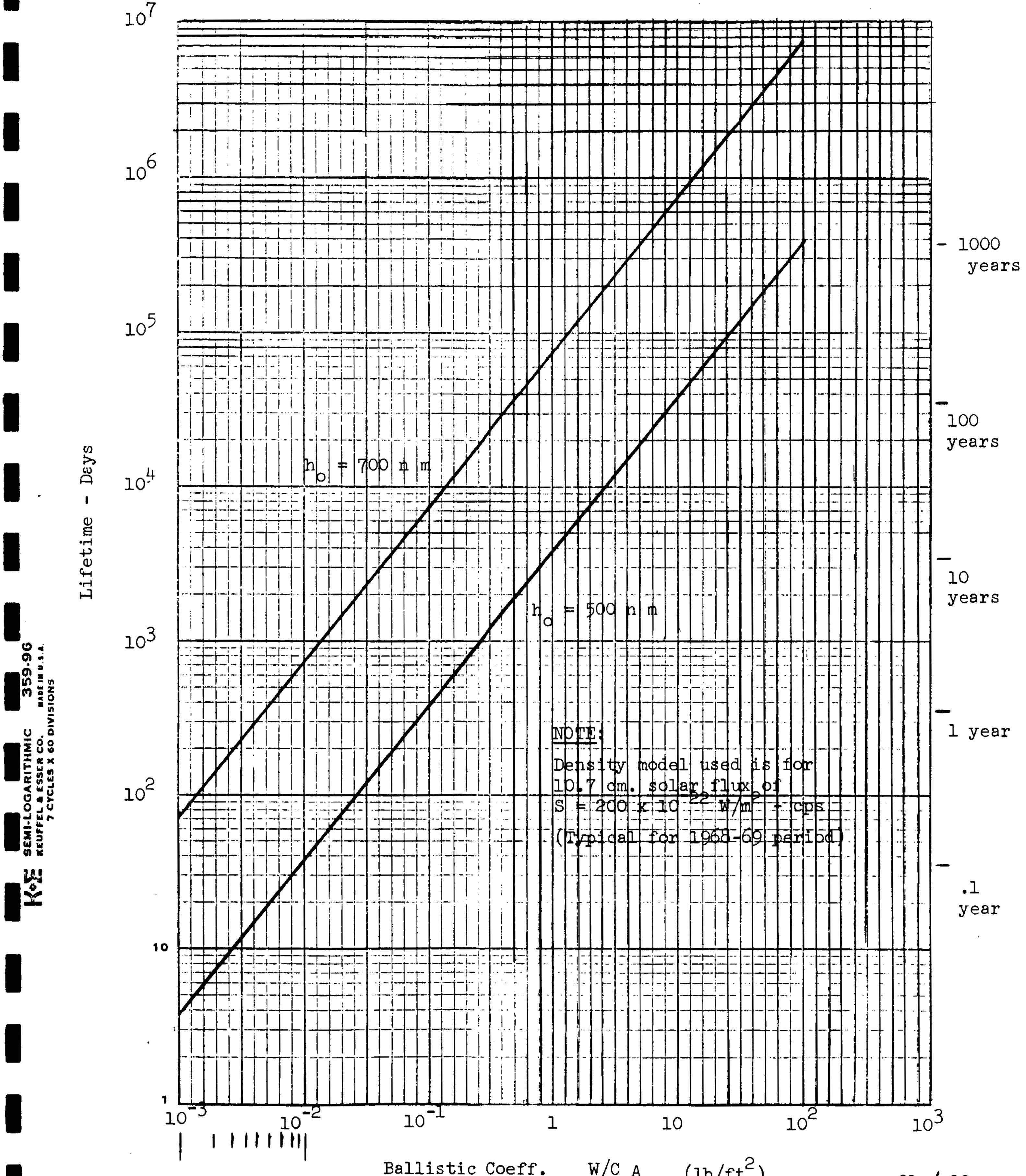
Item	Sketch	$\frac{W}{C_D A}$ (#/ft^2)	Area, Ft^2	Wt, #	Remarks
Apollo **CSM**		37.0	319	25,000	
		72.4	131	25,000	
(Tumbling)		55.7	225	25,000	
Baseline Design (PasComSat)		0.0054	--	784.3	With film on Lens
		0.012	--	784.3	<u>NOTE</u>: No Sail No Ames Booms
Baseline Design (PasComSat)		0.0034	--	405.2	Without Film on Lens
		0.0082	--	405.2	
Experiment Package		12.3	--	784.3	
		15.9	--	784.3	

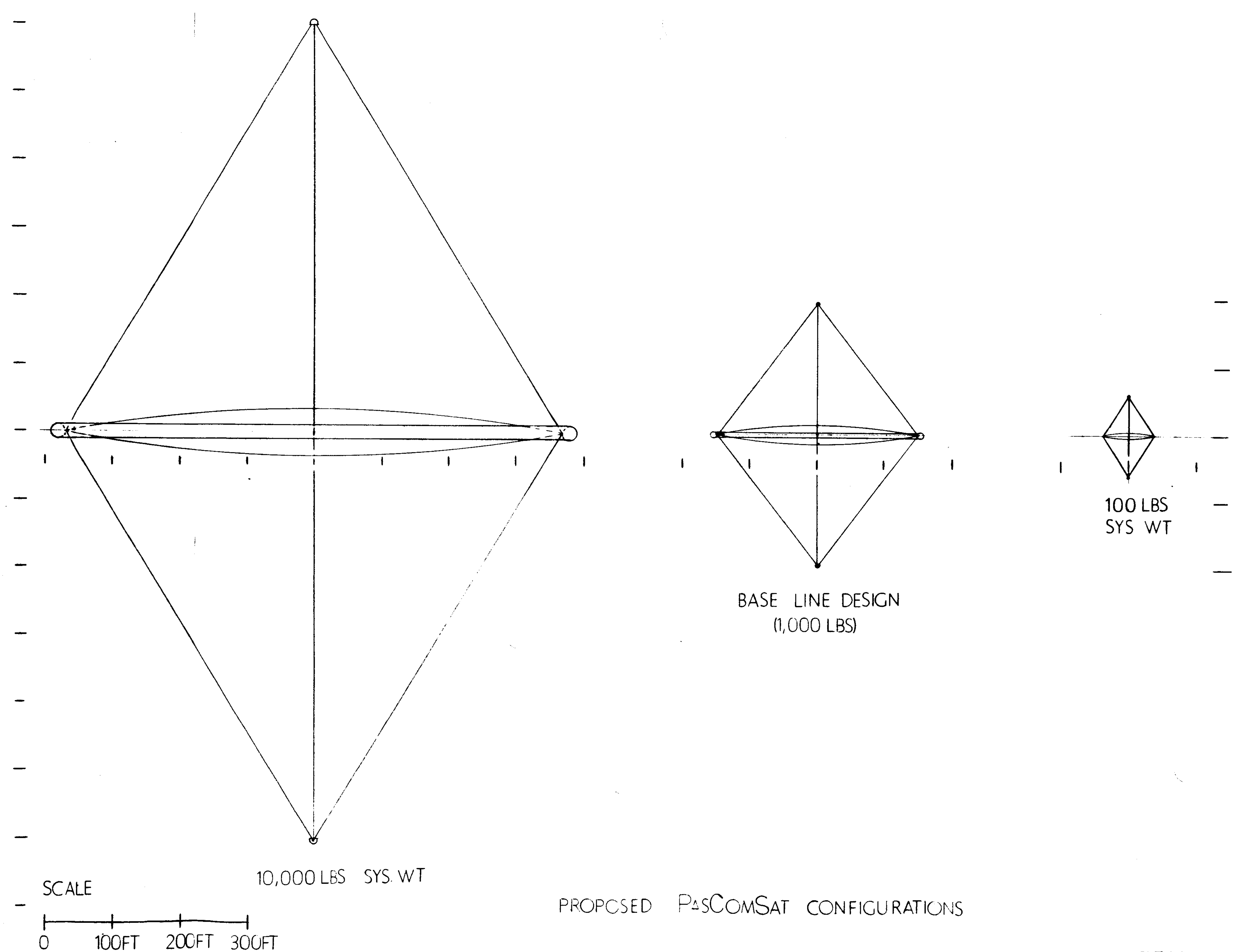


Assumed Density Profile

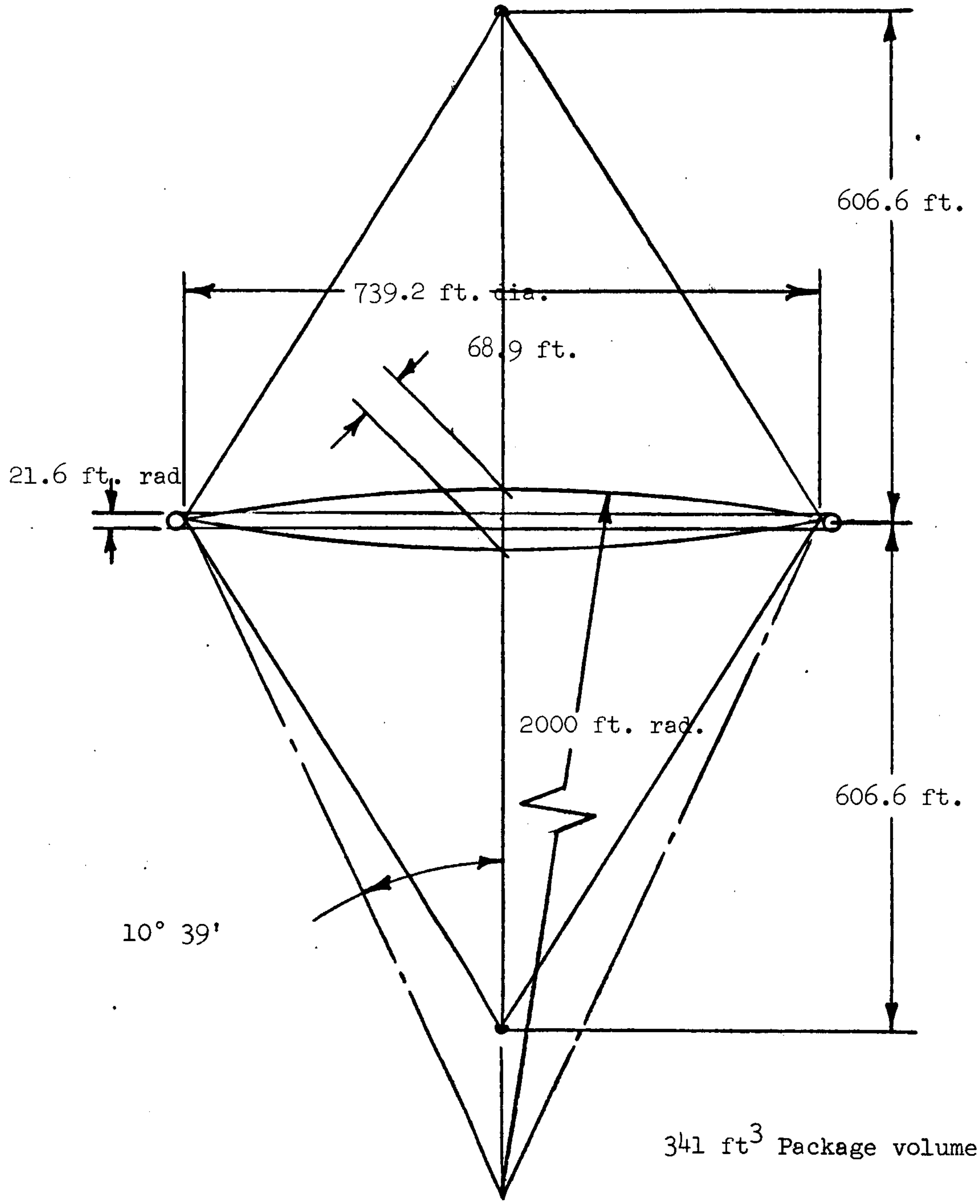
ORBITAL LIFETIME

EXCLUDING SOLAR FORCES

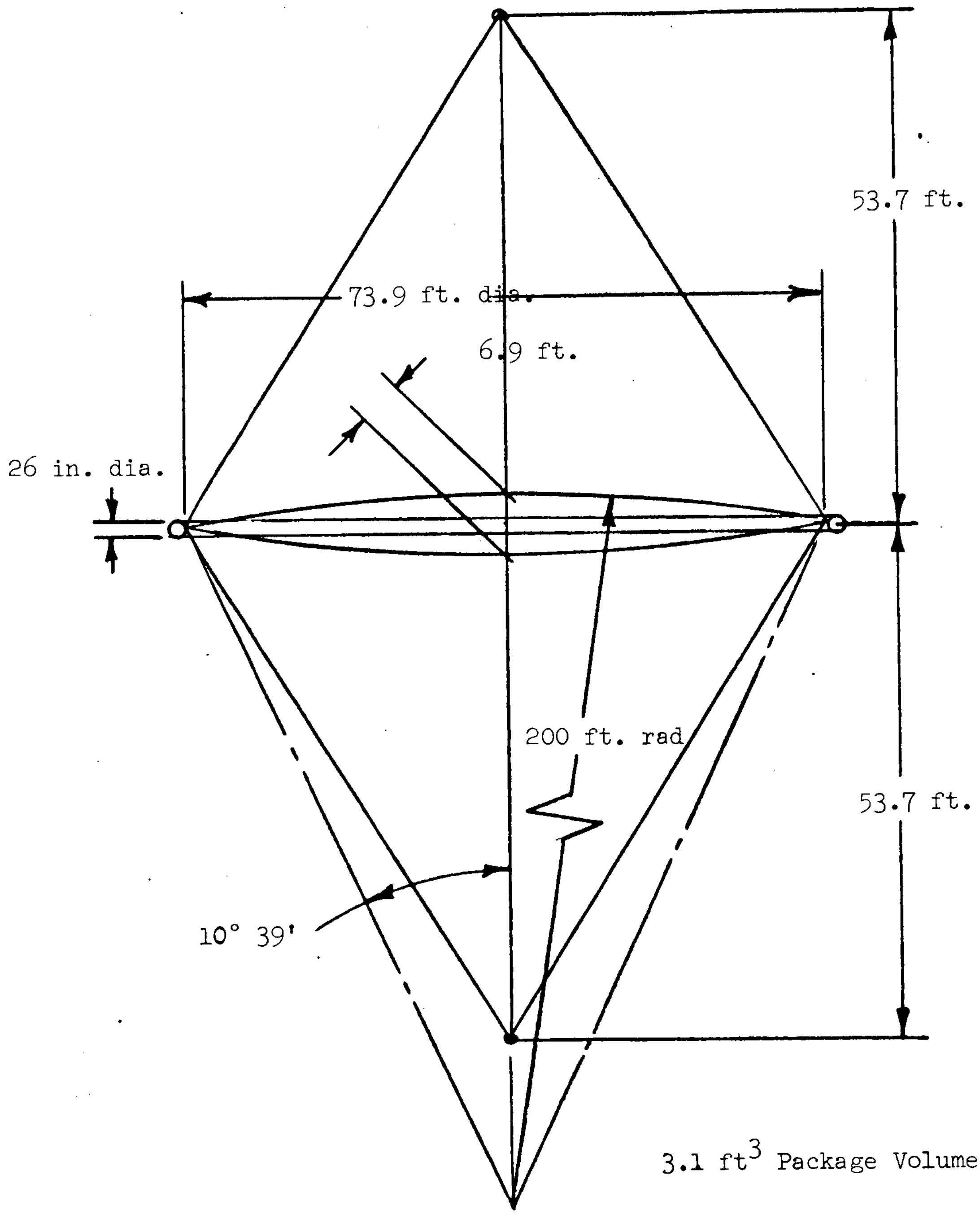




PROPOSED PASCOMSAT CONFIGURATIONS



10,000 lbs System Wt.



100 lbs System Wt.

OPTICAL PROPERTIES

Echo II Specular Material ρ = 800 ft.

Slant Range of 500 naut. mi.

SM = -6. (2 magnitudes brighter than Venus)

See it in daytime

(Specular)
Dark Photolyzable Grid Film on

Slant Range of 500 naut mi

SM = -4 (Same Stellar Magnitude as Venus)

Film Photolyzed off
Grid Sphere Grid

Slant Range 500 naut mi

SM = -2

INSTRUMENTATION LIST/EQUIPMENT

FUNCTION OF INSTRUMENT AND EQUIPMENT ON PAYLOAD

I. Vidicon Camera, Camera Control and Transmitter

(1) Canister - To take pictures of the Lenticular deployment. Later use to check on photolyzation of the Lenticular.

(2) SIVB - Monitor Lenticular deployment assurance against "hang up".

(3) CSM - Same as SIVB plus view the lenticular from different angles during fly around maneuver.

(4) RMU -

II. Command Receiver

Control the valve during the inflation sequence and the Vidicon Camera and battery during photolyzation check sequence.

III. Beacon

For tracking the lenticular during its orbits and guide for docking during the "bnckling" test.

IV. Transmitter

Telemeter the pressure, temperature and altitude of the lenticular during deployment, inflation and rigidization of lenticular for control of deployment cycle.

V. Battery Pack, Regulator, and Solar Panels

Battery pack to supply power to the complete system during deployment. The solar panels recharge the battery for use with the television transmitter for photolyzation studies.

VI. Transducer (Pressure, Temperature, Altitude)

To be used with the deployment and stabilization sequence for control and as engineering data.

VII. Solenoids

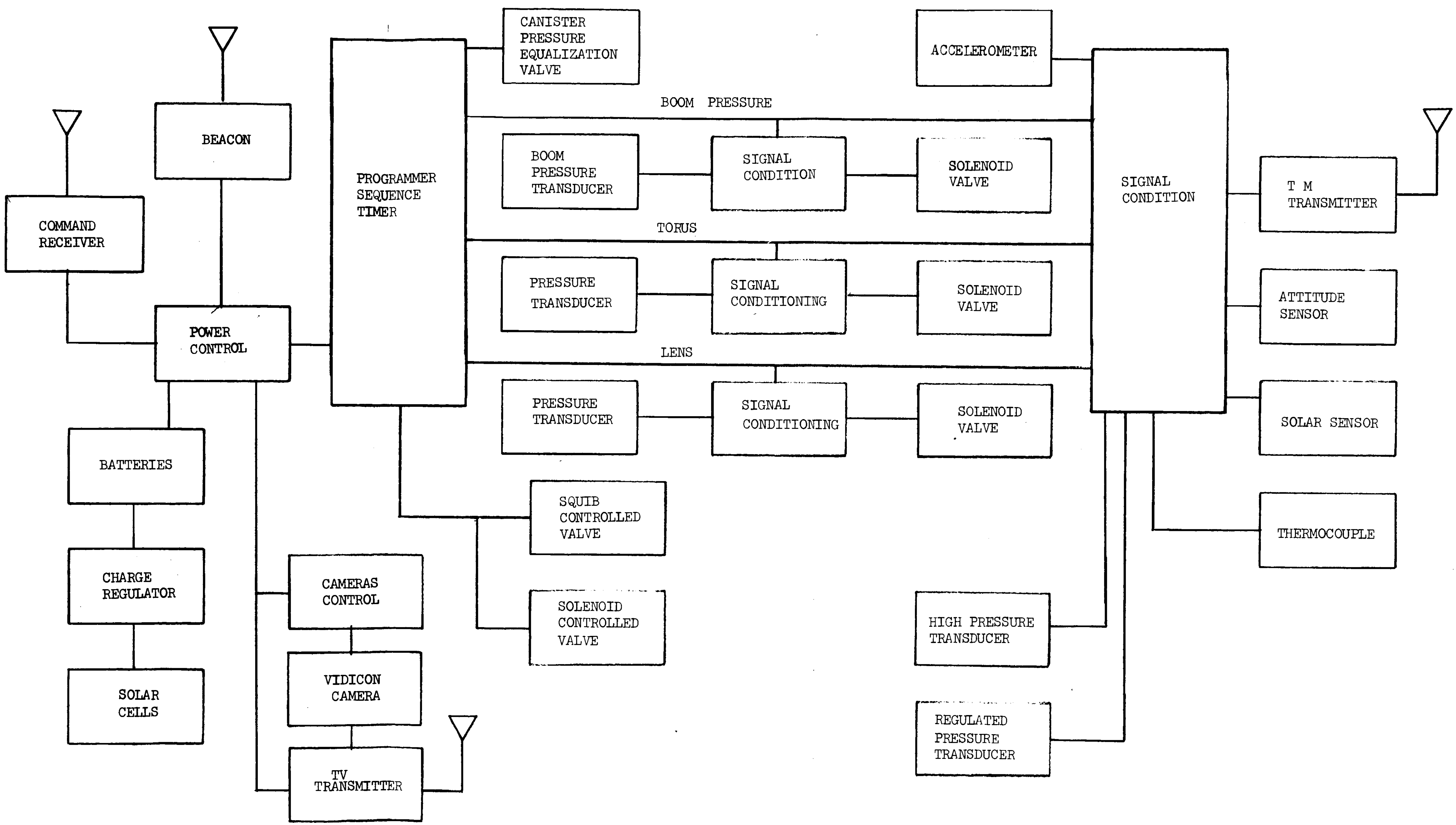
To control inflation gas during deployment.

VIII. Signal Conditioning and Program Sequence Timer

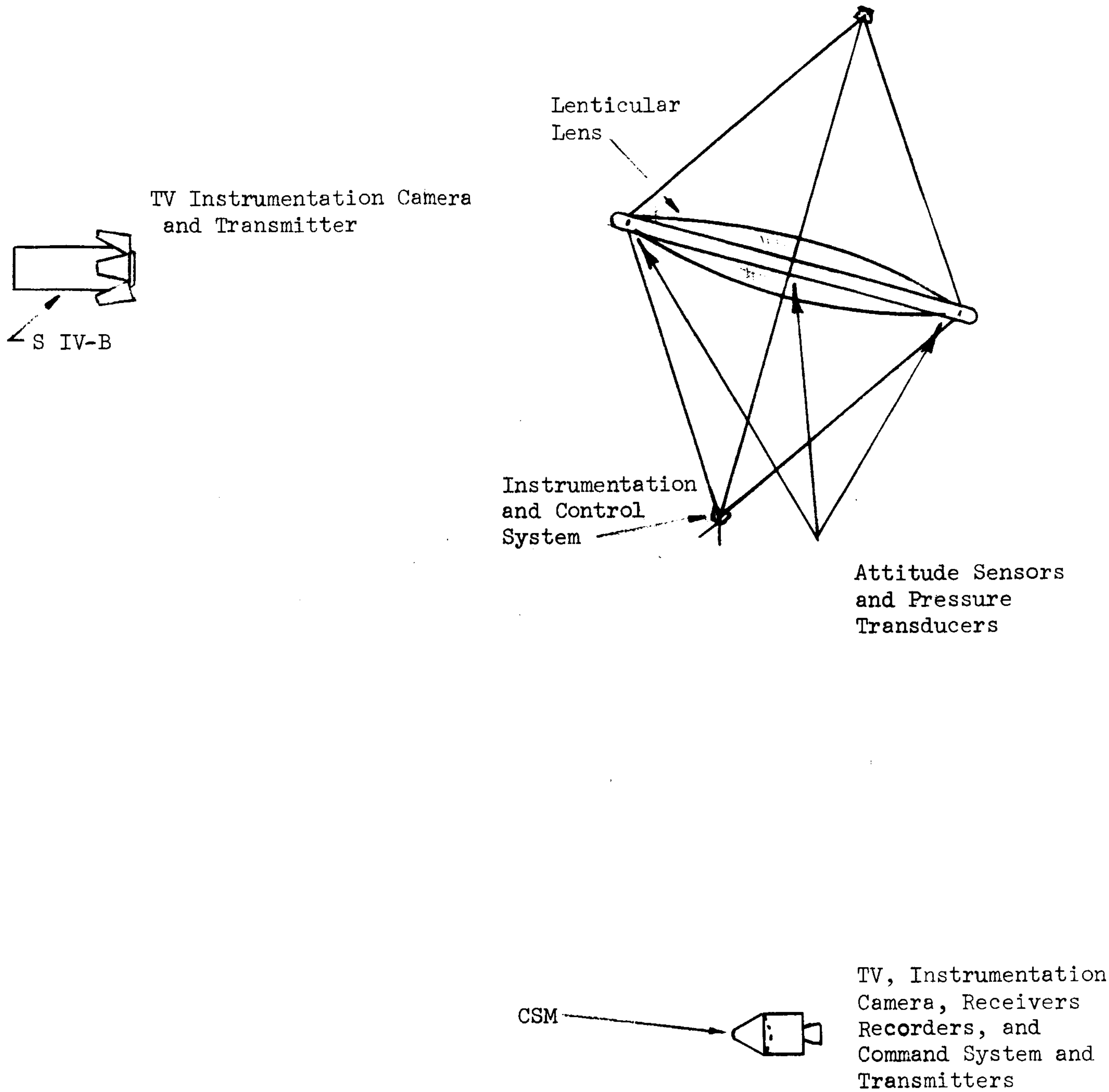
Circuits to integrate the components into a control and data acquisition system.

INSTRUMENT AND EQUIPMENT ON PAYLOAD

Item	Wt. (lbs)	Size (In^3)	Power Req.	Remarks
Vidicon Camera Camera Control	7	200	7 watts 28 volt	Lear Seigler Model 0431C
Transmitter	22	825	450 watts	Model 0663A
Battery	55	100		30 V-20 AH NiCad
Accelerometer	0.5	2	15 ma	
Beacon	1	22	16 ma	
Command Receiver	2.5	100	30 ma	
Transmitter	1.5	20	40 ma	
Transducer				
Torus Pressure	0.5	6	28 V/20 ma	0.152 psia (0.79 torr)
Lens Pressure	0.5	6	20 ma	0.0000245 (12.7 microns)
Boom Pressure				
Supply Pressure	1.5	2.5	5 V/15 ma	3000 psia
Regulated Pressure	1.5	2.5	5 V/15 ma	5 psia
Solenoids				
Signal Conditioning	5	100		
Program Sequence Timer	2	30		
Antennas (TM and command)	4			



INSTRUMENTATION AND CONTROL ON PAYLOAD



Instrumentation and Control System for Deployment, Inflation and Rigidization

FINAL REPORT OUTLINE

Frontispiece - Sketch

Foreword

Summary

Introduction - schedule, references

Technical Discussions
- A. General - Purpose of section, program plan, GTD plan
- B. Experiment Test Modes - 2 of them, sketches
- C. Base Line Design
  - (1) General - Orbital considerations, lifetime data, synchronous orbit effects
  - (2) Deployment and Rigidization
  - (3) Structural Evaluation
  - (4) Material Properties
  - (5) RF Evaluation
  - (6) Operational Characteristics
- D. Man's Participation — Dees/LTV
  - (1) Why Man/Where Man
  - (2) Task Analyses
  - (3) Time Line Analyses
  - (4) RMU/AMU Status
- E. Fabrication Studies
- F. Discussion of Problem Areas — Follow-on effort

Conclusions and Recommendations — Summarize follow-on effort

Appendices

References

Distribution List

NASA Form 1138

Low Altitude vs Synchronous Altitude Test

FINAL REPORT INPUTS FOR 5 SPECIALTY AREAS

(a) General

State of the art for this area - Theoretical Analysis, Tests

References

Basic Tables, Sketches

(b) Ground Test Development Status

(c) Space Test Development Status

(d) AAP Experiment Definition - Tabulate Data, Range, Tolerances, Accuracy

(e) Instrumentation and Equipment Requirements (Tables)

(f) Recommended New Work

(g) Summary

STABILIZATION AND DAMPING

AUGMENTED GRAVITY GRADIENT STABILIZATION SYSTEM CHARACTERISTICS

1. Provide 2 axis earth orientation satellite attitude control.

2. Accuracy
   $0.5°$ accuracy about the pitch and roll axes. The satellite is uncontrolled about the yaw axis.

3. Control Torque Capability
   Use 0.1 lb. thruster, located on canisters which are displaced 194 feet below satellite center of gravity, providing 19.4 lb. feet of torque. Assuming that the satellite pitch axis and roll axis inertias are of the order of 250,000 slug feet^2, the angular acceleration capability of the control system is 1.16×15^{-5} radians/sec^2.

4. The ratio of the augmentation jet control torque to the maximum gravity gradient torque, for a 500 nautical mile orbit, is approximately 60:1. Thus the augmented system has a greatly increased speed of response and easily overcomes any attitude disturbances encountered in the 500 mile altitude.

5. Attitude perturbing torque:
   (a) Solar pressure - 0.05 lb feet
   (b) Drag - 0.01 lb feet

   5 lb/sq mile, 2% cg cp displacement

$$T = 5 \times 190 \times .02 \times \left(\frac{267}{5280}\right)^2$$

6. Inversion capability provided by the jets and the horizon scanner.

7. Fuel consumed during 1 month operation assuming 5% duty cycle in both the pitch and roll axes and using hydrazine with a specific impulse of 235 sec.

$$W_{hydrazine} = \frac{2 \times 30 \times 24 \times 60 \times 60 \times 0.05\ (0.1)}{235}$$

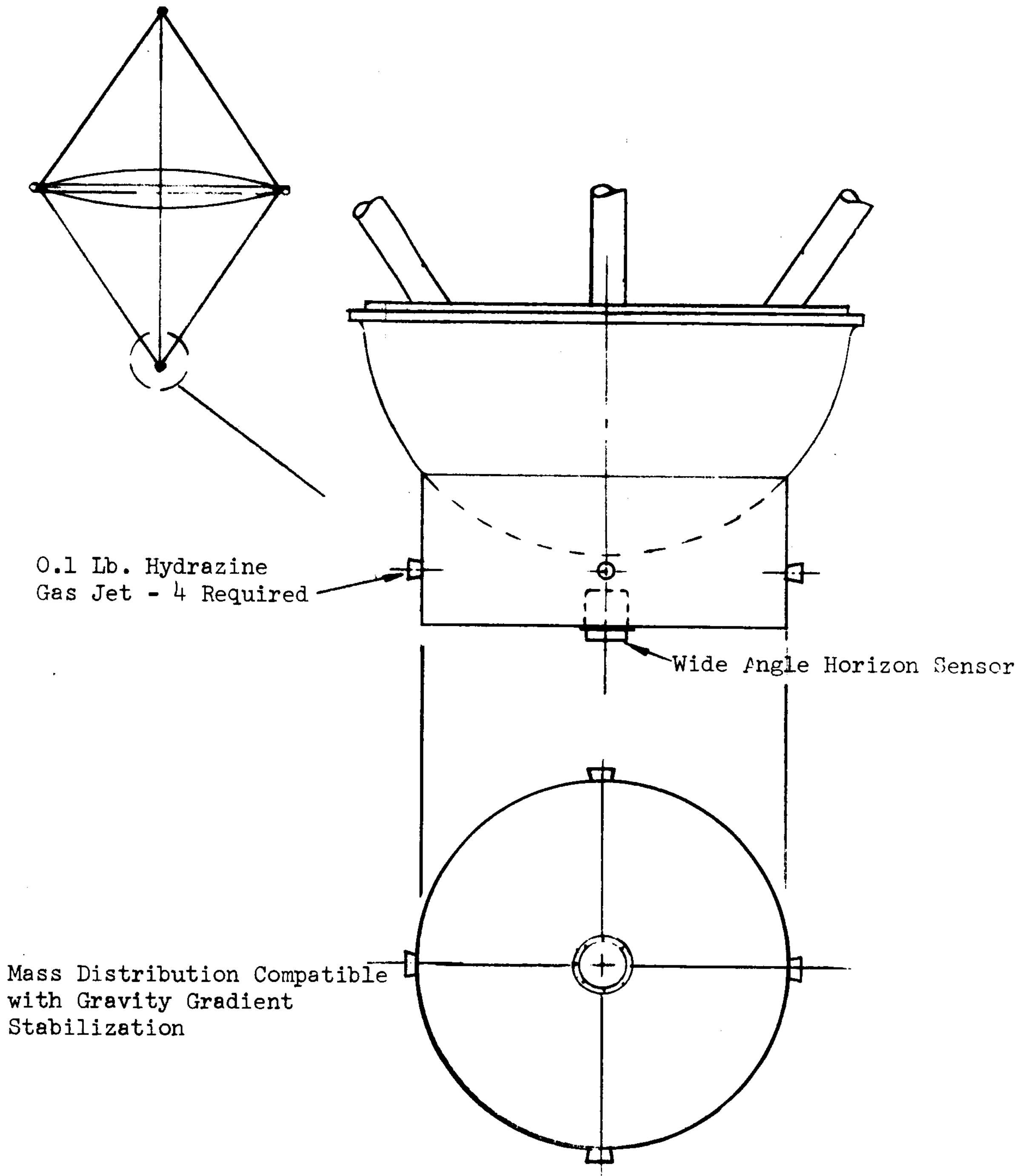
$$= 110 \text{ lbs/month}$$

8. Tankage volume for 1 month supply

$$\delta = \text{density} = 0.036 \text{ lb/cu in}$$

$$Vol_{tank} = \frac{110}{0.0364} = 3000 \text{ cu in}$$

$$Vol_{tank} = 1.75 \text{ cu ft}$$



Passive ComSat with Jet Augmentation and Damping of
Gravity Gradient Stabilization

RF EVALUATION EXPERIMENT

AAP RF EXPERIMENT FOR LOW ORBIT EXPERIMENT WITH THE LENTICULAR SHAPE, THE COMMAND SERVICE MODULE, AND EITHER THE SIV-B OR THE RMU

General

The proposed r-f experiment to support the deployment and other experiments consists of two fundamental parts, a set of in space radar reflectivity measurements, and a set of communication experiments between points on the earth's surface. These two sets of measurements will be made in the same time period as independent efforts. However, the results and data from each will be used in support of the other experiment, and the combined data will be used to provide an overall evaluation of the passive satellite.

The detailed radar cross section data is intended to provide a detailed evaluation of the reflection performance of the various parts and to provide an initial evaluation of the satellite performance. These data should be in sufficient detail to support later passive satellite developments.

The communications tests provide an initial measure of performance and a means whereby life data can be obtained through a periodic series of measurements.

The communications experiments are not sufficient in themselves to provide adequate data to completely evaluate the satellite. Specifically, no detailed evaluation of the r-f design of the satellite is possible, nor would it be possible to explain any peculiarities of the data, nor to accurately establish the critical mechanical elements of the deployed configuration. Similarly ground based radar reflectivity measurements will not provide the amount of data required for suitable evaluation within a reasonable time period.

A large amount of data is required due to the inability to make detailed measurements of suitable scale models on the ground and the wide range of frequency and aspect parameters which are of importance to a passive satellite. While it will be possible to verify that this device has real promise, its size is such that the only appropriate measurements can be made while it is in orbit.

If all measurements were made from ground based instrumentation, a modest measure of the success of a particular passive satellite could be achieved; however, no building block data useful in later experiments would be obtained (as witnessed by problems encountered with the ECHO program).

Radar Reflectivity Experiment

The purpose of these experiments is to obtain data from which details of the deployed PasComSat which affects its use as a passive satellite can be deduced. To achieve this objective, far field measurements at a large number of specific frequencies and over a wide range of aspect and bistatic angles is required. The specific parameters which have been selected are given in Table I.

A specific separate package for the instrumentation of this experiment is recommended. This package would be attached to the PasComSat package and would be attached to the CSM for the measurement program. By using a separate self-contained package, modifications to the CSM for the conduct of the experiment are eliminated or drastically minimized. A portable remote-control unit may be carried aboard the CSM or retrieved from the Instrumentation Package.

The fundamental experiment consists of monostatic and bistatic measurements made with the pulse radar of the Instrumentation Package at a range of 30 or more miles. See Figure 1. Aspect angle will be changed by oscillating the spacecraft (either through its natural motion or through use of control jets). To minimize the time required to cover all aspect angles and frequencies, the radar frequency would be cycled repeatedly through the selected frequencies in rapid succession.

To obtain bistatic measurements, transponder balls would be ejected. These would receive the reflected r-f energy from the PasComSat, use the received power level to modulate a telemetry transmitter, and transmit a signal to the Instrumentation Package. It is estimated that three such 'balls' should be sufficient to obtain an adequate coverage of the angular region of interest.

In order to calibrate the radar reflectivity systems, inflatable spheres would be ejected from the SIV-B (See Figure 1). These would be one to two meters in diameter, highly reflective, and rigidly inflated. The CSM would be maneuvered to point the large antenna of the radar cross section instrumentation package at the reference sphere for calibration.

The acquired data, which must include three axis attitude data on the PasComSat correlated in time to the radar measurements, would be stored for telemetry to the ground at appropriate times in the experiment cycle. There is the possibility that a rapid data processing and a flexible test schedule based on the reduced data may be implemented.

It should also be possible to obtain correlation with data obtained by ground based radars. These latter can obtain data for one or a few frequencies and at a few aspect angles. While this data is too sparse to be generally useful, some checkpoints will be of help.

The equipment in the instrumentation is shown in a conceptual block diagram on Figure 2, with the weight, power, etc. given in Table II. As is evident, the antenna would be an erectable array consisting of unfolding flat panels (see Figure 3). These may be deployed either manually or automatically with monitoring and backup provided by the astronaut. While some source of internally contained power is required, the main power source may be acquired either from the CSM (an umbilical connection) or from solar cells worked into the surfaces of the antenna. The command transmitter antenna may be readily provided by a wire antenna taped temporarily to a port of the CSM.

Communications Experiment

During the course of the reflectivity experiments and while vehicle attitude data is being obtained on the PasComSat, it is proposed that (whenever the satellite is in view) communications experiments be conducted with all available ground stations. Since the PasComSat should be visible during some daylight hours, optical tracking systems might be used and a large amount of data obtained by fairly simple systems. Due to the large difference in the relative magnitude of radar cross section of the PasComSat compared to the CSM and other objects involved in the experiment, no problems are anticipated from this latter device.

Table I . RF Experiment Requirements

Experiment	Parameter	Range	Tolerance
Radar Cross Section To evaluate: Surface tolerance; Seam effects; Diffraction effects; Blockage; Canister, Booms; Vehicle interference; Boom tolerances; Surface transmissivity effects; Fading effects, And to evaluate composite total performance	a) Frequency	1.0-2 gHz Vary in small increments to separate effects (blocking, fading, and transmission effects).	Kilohertz tolerance
	b) Range	23-40 miles minimum as f (frequency) 40 - for null investigation.	
	c) Aspect angle	± 20° minimum	
	d) Bistatic angle	0 - 40°	
	e) Polarization	2 linear CP for cross check of boom effects	1 db
	f) Modulation	Pulse	.8 μsec min pulse length
Communication Test To evaluate effects and extent of fading and scintillation; and to provide a means of obtaining "Life" data.	a) Carrier frequency b) Single vs double sideband c) Transmission clarity d) Signal to noise		

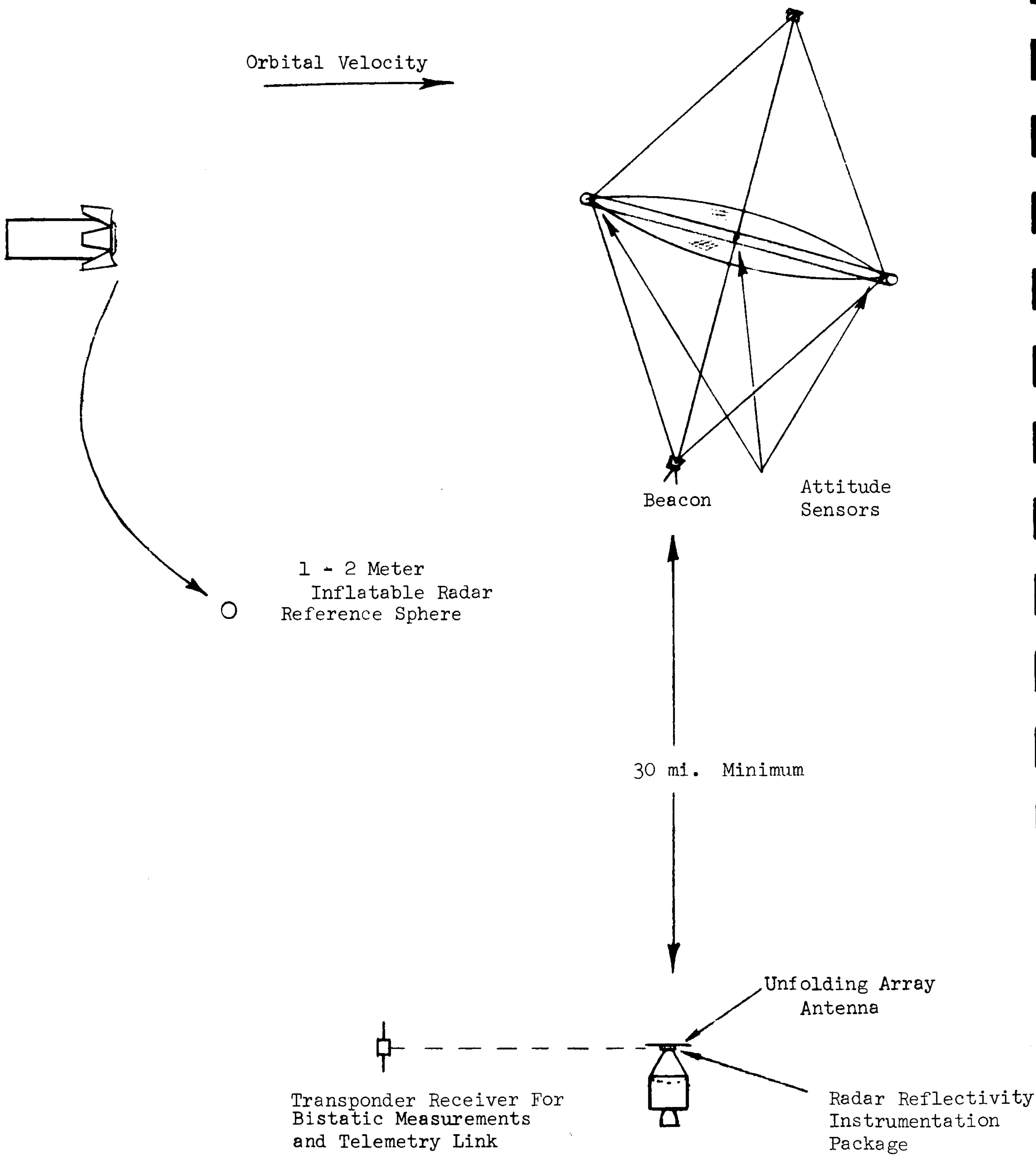


Figure 1. RF Evaluation

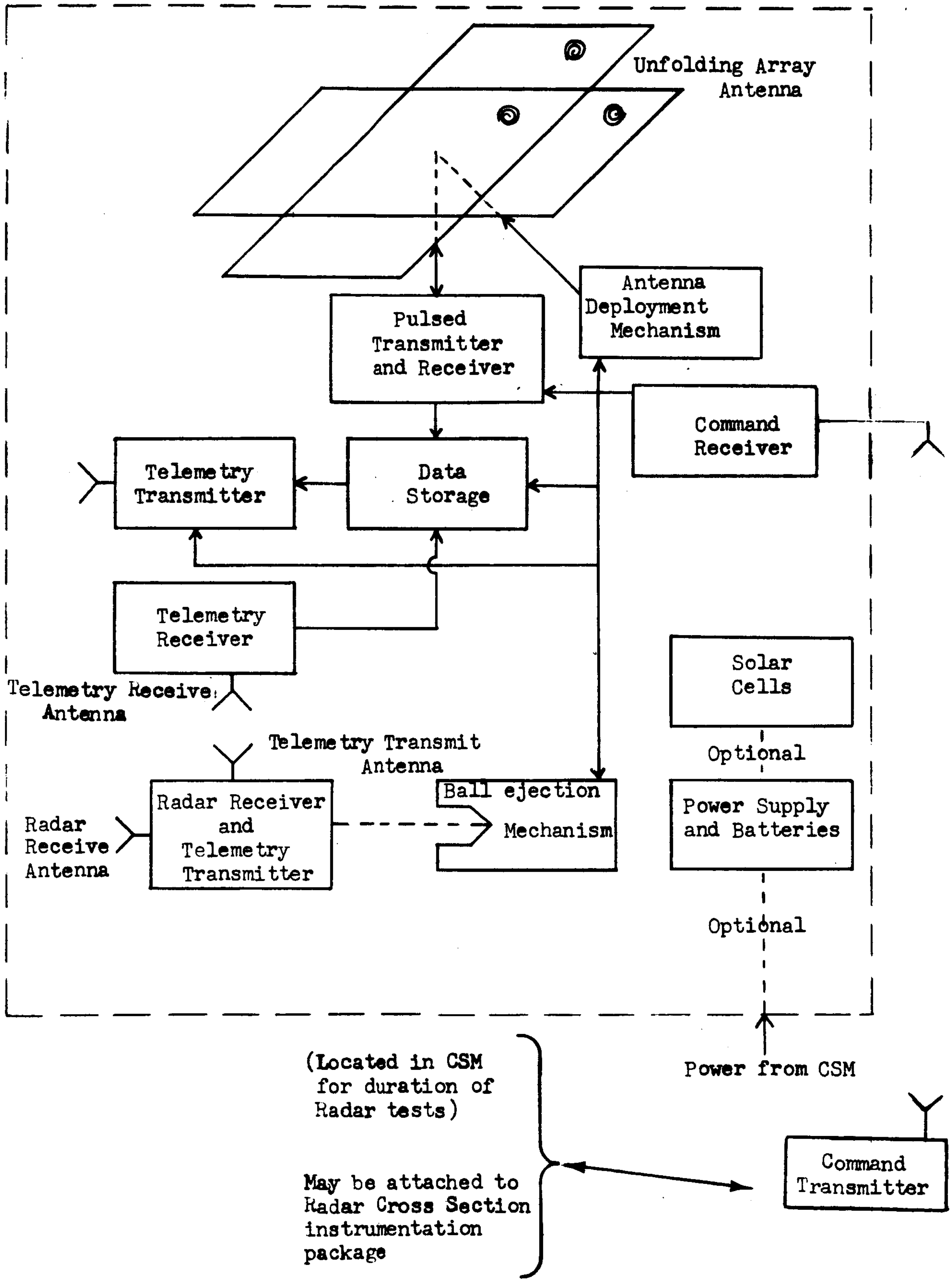


Figure 2 - Block Diagram of Radar Reflectivity Instrumentation Package for Attachment to CSM

Table II. RF Experiment Component Parameters

Experiment	Weight	Size	Power Required
Radar Cross Section (airborne only)	150	5 ft^3 plus antenna	1 - 10 KW
Communications (monitor gear only)	15	1/2	10 watts

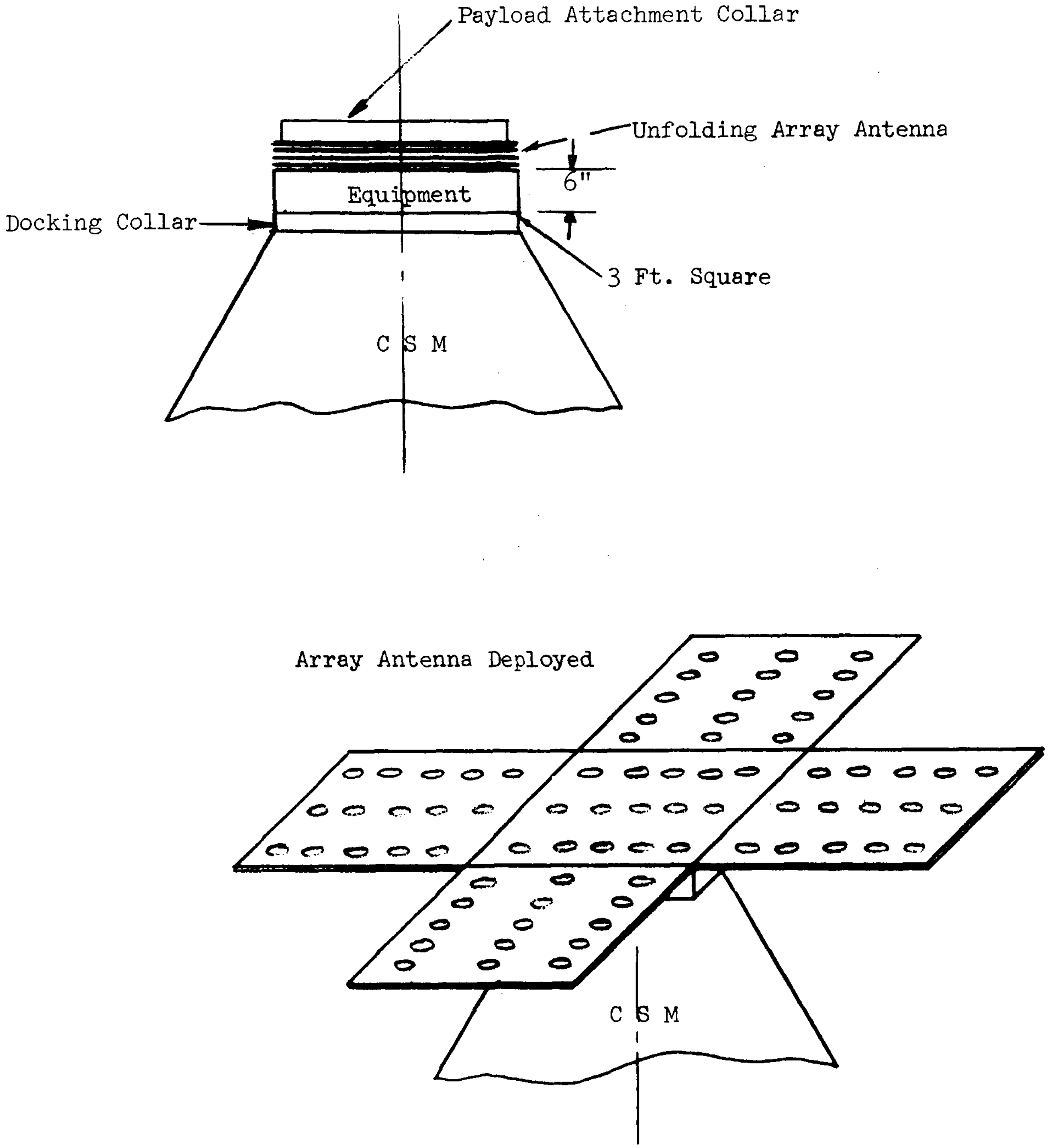


Figure 3 - Radar Reflectivity Instrumentation Package

ASTRONAUT PARTICIPATION

WHY MAN/WHERE MAN?

Provide complete and meaningful observations

Simplify procedures, appartus and data gathering

Perform malfunction identification and recovery

Provide in site judgment of unsheduled events.

MAN'S GENERAL FUNCTIONS

Initiate and stop action

Inspect and monitor

Correct malfunctions

Data taking - photography

- test equipment

Coordinate

THE DEPLOYMENT AND TESTING OF A PASSIVE COMMUNICATION SATELLITE

The passive communication satellite must have the capability of deploying automatically without any control by a man at the scene, if it is to be a practicable system. To insure this capacity in future operational missions, it is necessary to obtain as much data as is possible on the deployment and functioning characteristics of this experimental PasComSat. In any area of research in which there is uncertainty as to what will be measured or where the measurements may be taken, a real time ability to sense developments and correct a measurement program to account for these developments is required. A man controlling an investigation can usually perform this function well. Uncertainties concerning the nature of the deployment and the effect of the environment on the structure of the PasComSat do exist. The use of a man to adjust the measurement program is the most versatile and efficient solution to this problem.

The results of the recent Gemini missions indicate that until our EVA technology is considerably expanded, the inclusion of EVA in any program will detract significantly from the probability of a successful mission. Therefore, EVA will be kept to a minimum in this experiment. Two experiment modes are presently under consideration. Mode "A" uses the S IV-B as an instrumentation mount and uses the CSM to transport the canister to its deployment position. Mode "B" uses the RMU as the transporter and an instrument mount. In both cases, instruments are mounted on the CSM and on the booms of the satellite.

Man's most valuable contribution aside from his general ability to look for, record and adjust to the unexpected will be the visual monitoring and inspection with the subsequent identification and photographing of possible problem areas. This task is identified in the task analysis and timelines of Tables III through VI.

The retrieval of data packages from the satellite and either the S IV-B or the RMU requires a human factors tradeoff. In order to bring the data packages into the spacecraft, it is necessary to depressurize the spacecraft. Since data must be obtained from several different locations, there must be several pressurization cycles or the CSM must be maneuvered by an astronaut in a pressurized suit. Since spacecraft maneuvers in a pressurized suit have not yet been attempted, it might be wise to limit the number of data retrievals to a number compatible with the pressurization requirements of the mission with one pressurization cycle allocated per data package.

A rudimentary check of the orbit at 500 nautical miles indicates an orbital period of approximately 6200 seconds with about 4000 seconds of daylight available per orbit. The deployment, check of structural integrity and retrieval of the data are estimated to require 3625 seconds for Mode A and 4172 seconds for Mode B. If necessary, the data retrieval can be postponed for an orbit.

Tables V and VI are a task analysis and a time line for Mode B (with RMU). The RMU for this operation would have a 3000 pound-second propulsive capability, an electrical power capacity of 4 hours and would weigh about 180 pounds. The unit would include a motion picture camera, RF measurement sensors and an attitude reference system. It would also have provisions for docking to the S IV-B and the APOLLO and a means of carrying and releasing the PasComSat payload. Redocking the RMU with the S IV-B at the conclusion of the deployment phase would permit refueling and possible later RMU applications. The long translations of the RMU are assumed to be made at a velocity of 10 feet per second. All other RMU translations are assumed to be at five feet per second. If slower translation rates can be tolerated, a considerable reduction in fuel consumption can be realized.

Table III Task Analysis
Deployment and Structural Integrity Check of PasComSat
Mode A: Without RMU

1. Assumptions

   a) The baseline configuration is used.

   b) The orbit altitude is 500 nautical miles circular.

   c) The canister is located on the SSESM rack in a position suitable for docking with the CSM.

   d) The CSM is docked with the canister.

2. Deployment

   a) Visually inspect canister from within CSM.

   b) Release canister from the SSESM rack, position it 600 to 800 feet directly in front of the S IV-B.

   c) Position CSM 600 to 800 feet away from canister in a direction at a right angle from a line drawn between the canister and the S IV-B.

   d) Command actuation of film and other recording devices on the CSM and the S IV-B.

   e) Command and control inflation of PasComSat.

   f) Record measurements of inflation of PasComSat.

   g) Perform satellite distortion check.

3. Structural Evaluation

   a) Structural Integrity

   CSM will be maneuvered sufficiently to allow a thorough visual inspection and photographing of the surface of the satellite.

Table III - Task Analysis (Continued)

4. RF Evaluation

Launch transmitters will control recording equipment.

5. Retrieval

Data can be retrieved from the PasComSat and SIVB by EVA on a short tether/umbilical from CSM.

Table IV - Time Line Analysis
Deployment and Structural Integrity Check of PasComSat
Mode A: Without RMU

Event	Command Astronaut	Time-Seconds Event	Time-Seconds Cumulative	Experiment Astronaut
1	Visually inspect canister	120	0	Visually inspect canister
2	Dock CSM to canister/SIVB	600	120	
3	Visually inspect canister	120	720	Visually inspect canister
4	Release canister from SIVB	10	840	
5	Position canister 800 ft in front of SIVB	80	850	
6	Release canister	10	930	
7	Remove CSM 800 ft away from canister, 90° to original path	80	940	
8	Release canister	30	1020	Command actuation of all remote monitoring and recording equipment
9	Station-keep	85	1020	
10		15	1050	Actuate all on-board monitoring and recording equipment
11		10	1065	Initiate shaping
12	Photograph PasComSat at deployment (Third astronaut would do this)	60	1075	Monitor and control shaping
13	Inspect for problems	60	1135	Inspect for problems
	If problem occurs, include events 14-17			
14	Translate to vicinity of problem	100	1195	
15		60	1295	Photograph problem
16		120	1355 1475	Attempt to solve problem by pressure manipulation
17	Withdraw to a "safe" distance	50	1475	

Table IV - Time Line Analysis (Continued)

Event	Command Astronaut	Time-Seconds Event	Time-Seconds Cumulative	Experiment Astronaut
18	Station keep	30	1525	Initiate rigidization
19	Fly inspection pattern	780	1555	Inspect and photograph
20	Translate to tip of booms (within 25 feet)	50	2335	Secure helmet
21		60	2385	Check umbilical and tethers
22	Depressurize Apollo	60	2445	
23		30	2505	Open hatch
24		60	2535	Exit hatch
25		60	2595	Move to apex of booms using HHMU
26		60	2655	Attach connecting line to camera
27		30	2715	Activate camera release mechanism
28		60	2745	Return to CSM
29		60	2805	Enter hatch
30		60	2865	Close hatch
31	Pressurize Apollo	60	2925	
32	Translate to within 25 ft of SIVB	100	2985	
33	Depressurize Apollo	60	3085	
34		30	3145	Open hatch
35		60	3175	Exit hatch
36		60	3235	Move to SIVB using HHMU
37		60	3295	Attach connecting line to camera
38		30	3355	Activate camera release
39		60	3385	Return to CSM
40		60	3445	Enter hatch
41		60	3505	Close hatch
42	Pressurize Apollo	60	3565	
	Total Time		3625	

Table V - Task Analysis
Deployment and Structural Integrity Check of PasComSat
Mode B: With RMU

1. Assumptions

   a) The baseline configuration is used.

   b) Orbit is at 500 n.m.

   c) The canister is located on the SSESM rack.

   d) Canister is mounted on RMU which is attached to the rack and has a docking collar.

   e) CSM is docked with RMU or canister.

2. Deployment

   a) Visually inspect canister from CSM or by EVA astronaut on a tether.

   b) Release, remove and position RMU and canister with CSM (600 to 800 feet from CSM).

      (Release must be remotely operated from CSM)

   c) Properly orient RMU and canister by command from CSM.

   d) Command release of canister from RMU by CSM operator.

   e) RMU to withdraw 600 to 800 feet from canister and station-keep relative to canister.

   f) CSM to withdraw 600 to 800 feet from canister 90° to path followed by RMU.

   g) RMU operator activate RMU monitoring device and start video recording.

   h) CSM PasComSat operator control inflation of PasComSat.

      1) Shaping
      2) Rigidization

Table V - Task Analysis (Continued)

2. Deployment (Continued)

   i) Record on video tape and/or film the inflation and rigidization of PasComSat from cameras on both CSM and RMU.

   j) Satellite distortion check.

3. Structural Evaluation

   a) Structural Integrity

      RMU - fly pattern to inspect satellite exercising care not to interpose satellite between RMU and CSM. Some maneuvering by CSM may be required.

   b) RMU and CSM - at close range (ranging radar) photograph various elements (boom torus, etc. to determine by trigonometric relation the cross-section dimensional accuracy).

Table VI - Time Line Analysis
Deployment and Structural Integrity Check of PasComSat
Mode B: Without RMU

Initial conditions: Apollo CSM has separated from SIVB, transposed and is station-keeping approximately 10 feet from SIVB payload module docking collar.

Event	CSM Operation	Time-Seconds Event	Time-Seconds Cumulative	RMU Operation	RMU Propellant Expended (lbs)
1	Visually inspect RMU/ canister installation	60	0		0
2		540	60	RMU C/O and engine warm-up	.25
3		300	600	Rendezvous and dock CSM to RMU/canister	0
4	CSM withdraw 800' from SIVB	80	900		0
5	Move CSM 10 ft. from RMU/canister	30	980	Release RMU/canister	0
6	Withdraw CSM 800' from RMU/canister 90° to original path	80	1010	Orient RMU/canister for deployment (assume 1 pitch + 1 yaw maneuver and hold.	1.0
7		10	1090	Release RMU from canister	0
8		82	1100	Withdraw RMU 800' from canister 1 - 180° yaw + translate	1.0
9	Initiate shaping	10	1182	Stationkeep	
10	Monitor and photograph	60	1192	Monitor and photograph via RMU	
11	Inspect for problems visual	60	1252	Inspect for problems (TV)	.05
	If problem occurs include Events 12 through 14				

Table VI - Time Line Analysis (Continued)

Event	CSM Operation	Time-Seconds Event	Cumulative	RMU Operation	RMU Propellant Expended (Lbs)
12		100	1312	Translate to vicinity of problem (close-up view). Assume 1000' + 1 pitch and 1 yaw maneuver	1.0
13		60	1412	Examine problem (stationkeep 1 min)	.03
14	Initiate rigidization	30	1502	Stationkeep	.02
15	Monitor and operate self-contained cameras (time lapse, etc.)	780	1532	Fly inspection and gross measurement pattern. (Assumes 2 circumnavigations w/ 6 stops each)	6.0
16		300	2312	Translate and photograph components - record range	3.0
17		70	2282	Translate to within 20' of SIVB	1.0
		240	2622	Dock with SIVB	.42
		10	2862	Deactivate RMU	0
18		30	2872	Start refuel	0
19	Retrieval of data. (Same as operations 20-42 of Table IV)	1240	2882		
20		385	2902	Finish refuel	0
	Totals		4172		13.97

SUMMARY

WHAT REMAINS TO BE DONE

1. Complete experiment design drawings - Baseline, Instrumentation, Equipment List

2. Complete Form 1138

3. Final Report - Rough Draft, Approval, Modification, Distribution

4. Definition of Follow-on Effort

LTV Effort

(a) Supply Task and Time Line Analysis Data for Test Modes Anticipated

(b) Define EVA Support Equipment Requirements for Test Modes

(c) Supply Final Report Inputs

SUGGESTED FOLLOW ON PROGRAMS

1. Preliminary Design Studies - Materials Definition, Structural Analyses, Design Drawings, Instrumentation, Special Equipment
   - Rim Development Studies
   - Diaphragm Tests - Buckling Data
   - Thermal Distortion Considerations
   - Orbit Perturbation Studies - Drag, Solar Pressure Forces, Computer Program
   - Pressure System Development
   - Large Model Fabrication and Checkout

2. Active Stabilization and Damping System Studies
   - Control System Development for Baseline Experiment
   - System for Lens Only - Design Studies

3. Development of RF Transmitting Beacon-Ball System
   - Test Technique Development and Checkout
   - Ejection System Study
   - Define RF Equipment Package

ACTION ITEMS

1. Suggest Technical Briefing at NASA-Headquarters Soon

2. Suggest Technical Coordination Meeting with cognizant MSC and MSFC personnel